MANAGEMENT OF THE GHANA TROPICAL HIGH FORESTS

Evaluation of Forest Management in the Ghana Tropical High Forests

by

L.K. DANSO

A substantial essay submitted in partial fulfilment of the requirements for the degree of Master of Science (Forest Management) in the Department of Forestry, Australian National University.

1975

ORIGINALITY OF THESIS

Except where specific acknowledgement is given, THIS DISSERTATION is the author's own work.

ACKNOWLEDGEMENTS

I owe a continuing debt of gratitude to Dr Ross Florence for his constructive criticism on the general presentation of the subject, and for patiently reading through the subject matter and making very useful comments on phraseology, relevance, and sequence; and for also enabling me to share his wealth of experience in tropical forestry. I am further grateful to Mr E.D. Parkes for painstakingly going through the economics section and making critical comments on certain economic statements and for carefully directing my attention to the pertinent economic problems involved; and also to Philip West for his logical approach to computer programming and guidance in the regression analyses. I am greatly indebted to Dr Ian Ferguson for his valuable assistance in the choice of the subject for the substantial essay; for his flawless guidance and personal involvement in my welfare for at least two years and for enabling me to view things in their right perspective.

I wish to thank the Professor and all members of the staff in the Department of Forestry, ANU, who in one way or the other helped to make the course effective; also Mrs Paula Reid - the Librarian - for readily getting the correct references and for quick 'bon mot' in dull moments; Mrs Elizabeth Robinson for accepting the tedious job of typing the thesis and for excellent sense of duty; and to my wife Cecilia for bearing with me throughout the course.

Finally my greatest thanks go to the Government of the Commonwealth of Australia for offering me the scholarship to take the course, and to Mr John Francois - the Chief Conservator of Forests, Ghana - for releasing me for the course and enabling me to get the pertinent material for the thesis.

ABSTRACTS

The dissertation attempts to bring out some of the important factors - ecological, biological, environmental and sociological factors - affecting the management of the Ghana Tropical High Forests (GTHF). Emphasis, in this study of the GTHF, has been placed on the characteristics of the GTHF, the conditions under which they develop, and their employment as an important economic resource. The result is that some of the problems confronting management - problems of ownership, application of forest law, shifting cultivation, cocoa farming, development of forest industries, market imperfections, etc. - have been clearly revealed.

From the nature of the problems it has been made possible to make recommendations which seek to ensure the continued use of the GTHF as an important economic resource, and at the same time to reduce the conflicts among the factors referred to above so that the GTHF can be maintained as a permanent as well as a productive national asset.

Tables, Maps, Histograms and Graphs have been liberally used to illustrate as well as elucidate points of interest.

ABBREVIATIONS

ATP	African Timber and Plywood Ltd.
ACA	Antiaris Chlorophora Association
ANU	Australian National University
CTA	Celtis-Triplochiton Association
CCF	Chief Conservator of Forests
CSIR	Council for Scientific and Industrial Research
CLTA	Cynometra-Lophira-Tarrietia Association
FAO	Food and Agriculture Organisation
GTA	Ghana Timber Association
GTMB	Ghana Timber Marketing Board
GTHF	Ghana Tropical High Forests
GWA	Gliksten West Africa Ltd.
GDP	Gross Domestic Product
GSW	Guinea Savanna Woodland
LTA	Lophira Tarrietia Association
MPP or MPX	Marginal Propensity to Produce or Export
MEG	Minimum Exploitable Girth
PSP	Permanent Sample Plots
REX	Regression Analysis of Y and X
SPP	Species (Plural)
RME	Reliable Minimum Estimate
TOP	Times of Passage
TSS	Tropical Shelterwood System
WA	West Africa
WATRA	West African Timber Resources Association
WP	Working Plans

CONVERSIONS

AREAS:

1 Hectare (ha.)	=	2.5 acres (ac.)
1 Hoppus square foot (h.ft.^{2})	=	1.273 square feet (ft^2)
1 Hoppus square inch (h.in.^{2})	=	6.45 square centimetres (cm^2)
1 Square mile (sq.ml.)	=	640 acres (ac.)
	=	256 hectares (ha.)
	=	2.59 square Kilometres (Km^2)

DISTANCES:

1 Chain (ch.)	=	20.12 metres (m)
1 foot (ft.)	=	30.48 centimetres (cm)
	=	0.3048 metres (m)
1 mile (ml.)	=	1.61 Kilometres (km)

VOLUMES:

Volume in hoppus feet (h.ft.) = Volume in cubic feet x .785

WEIGHTS:

1 Long ton	=	2240 lbs
	=	1.016 metric tons
	=	1016 Kilograms

CURRENCY:

1 Dollar Australian (\$(Aust.)) = 1.57 Cedis (¢)
(March 1975)

LIST OF MAPS

LIST OF HISTOGRAMS AND GRAPHS

LIST OF TABLES

LIST OF CONTENTS

Page

CHAPTER 1

INTRODUCTION

An evaluation of management in the tropical high forests provides useful information on past achievements and failures; it reveals the relevance and practicability of standards already set and the necessity for revision of past standards and controls; and it provides a basis for determining the direction of future forest management.

The recent shift in emphasis in forest management in Ghana from complete reliance on natural tropical high forests towards greater attention to man-made forests calls for a thorough evaluation of the former methods of management so as to avoid unnecessary future incursions of man-made forests into the Ghana Tropical High Forests (GTHF).

As part of this evaluation a preliminary study is made of the use to which information from recently established permanent sample plots in the GTHF can be put. This preliminary study should also indicate the adequacy or otherwise of the data being collected from the sample plots, and where necessary, recommendations can be made to ensure a greater degree of relevance and accuracy of the data for future forest management.

1.1 METHOD OF APPROACH

The dissertation is in five parts - Part I deals with the Statements of Basic Facts relating to the Tropical High Forests of Ghana; in particular, to the location, area, ownership, legal position, ecological and biological conditions, and economic considerations. Part II deals with the Methods of Management applied to the GTHF, and Part III with the Economic Benefits for Management of the GTHF. Part IV deals with the importance of all the factors that affect silvicultural management of the GTHF, and the last part, Part V deals with the summary of all the recommendations mainly based on Part IV.

1.2 DATA COLLECTED AND LITERATURE REVIEWED

Relevant data to support statements made in this dissertation on the GTHF have been drawn from many sources, including a 5% enumeration survey of the GTHF, preliminary results of sample plot measurements, annual reports, economic survey reports and working plans of the Forestry Department, Ghana. Other data have been obtained from various reports of the United Nations Agencies and the Central Bureau of Statistics, Ghana. Some data have also been collected from different concession areas in the GTHF as a result of visits made personally in 1969 and 1972.

Many of the concepts developed in this dissertation have been drawn from ecological, biological, statistical and economic studies by various authorities in different parts of the world and also from personal experience. The main ecological and biological concepts concern the structure and composition of the GTHF, the distribution of trees by species and girth classes, the studying of trees currently considered of economic importance, soil plant relationships, and methods of management of these forests. These concepts are drawn from such studies as those by Dawkins (Oxford) based on his Uganda experience; Taylor (Edinburgh) and Jack (Ireland) on the GTHF, and Florence (A.N.U.) in Queensland.

Research on the tropical high forests is incomplete in any one region, thus it is necessary to collect ideas from different regions of the world to assist in building up a comprehensive knowledge about the GTHF. Statistical informations are mainly calculations and regressions based on lecture notes by Carron (A.N.U.), Ferguson (A.N.U) and P. West (A.N.U.). Ideas on forecasting, markets and market structure are all based on lecture notes and relevant references given on the course by Ferguson, Parkes and Reilly (All of A.N.U.).

PART I

CHAPTER 2

STATEMENTS OF BASIC FACTS

2.1 LOCATION AND AREA

The GTHF lie roughly between latitudes $5^{O}N$ and $7^{O}30'N$ of the equator and between longitudes $0^{O}30'E$ and $3^{O}30'W$ of the Greenwich Meridian (Map 1). The actual area of the closed forest zone is 31,760 sq. miles (8,130,560 ha.). Of this 18.93% or 6012 sq. miles (1,539,000 ha.) are permanently reserved forests.

2.2 OWNERSHIP

With the exception of very small alienations of land to a few families, all lands in the GTHF are the property of different ethnic groups, each ruled by a chief in whom the power over land is vested. All members of each ethnic group have usufructuary rights (i.e. rights of cultivation and not outright ownership of a piece of land, by each family of an ethnic group, and the enjoyment of its fruits) to the land. Such rights are granted by the chief after the performance of the necessary customary rites.

In 1897 some of the chiefs successfully resisted the introduction of a lands bill which would have transferred ownership of all lands in the then colony to the British Crown. This obviously discouraged any future attempts at transfer of land ownership, and this state of affairs remained unchanged at independence. With the introduction of national and local governments many of the powers of the chiefs and therefore of ethnic groups have gradually been eroded; however, the chiefs have continued to maintain their strong powers over their respective lands.

This anomaly appears to have been tolerated by various governments because the philosophy of the institution of chieftaincy has deep roots in land. The history, hierarchical organisation, group loyalty and norms of the ethnic groups conform to the customary rights over land. The retention of land ownership by chiefs appears to have some effect on the achievement of a coherent nationhood.

Ownership of land does not therefore alter at reservation, and chiefs receive a fair share of revenue from the sale of forest produce.

With the spread of shifting cultivation over most of the 25,748 sq. miles (6,591,488 ha.) of unreserved forest, coupled with the rapid political and socio-economic changes, it is becoming increasingly difficult for land owners to see the need for maintaining large areas of land under permanent natural forest in the presence of many alternative uses of land.

Many individuals having usufructuary rights on land have also been exerting mounting pressure for the release of portions of old as well as newly created forest reserves for farming. One forest reserve, the Desiri Forest Reserve (52 sq. miles or 13,312 ha.) has been so badly covered with illegal farms that its fate presently hangs in the balance.

The pressure for the release of forest lands has assumed such importance that the present government has found it necessary to set up a commission of enquiry into illegal farms.

Aristotle was certainly right when he said: "That which is common to the greatest number has the least care bestowed upon it".

2.3 LEGAL POSITION

The government has power to negotiate felling agreements on timber on behalf of the owners in order to achieve uniformity in the imposition of rents, royalties and other fees.

Felling of timber trees outside forest reserves is controlled by the Lands Department which is also heavily involved with land acquisition problems in cities and urban areas. The Chief Conservator of Forests (CCF) controls fellings in forest reserves, and he has overall power over the granting of Locality Marks (licences for logging in specified areas) throughout the GTHF.

Both the Forestry and Lands Departments collect royalties of trees felled in their respective areas, but all disbursements of money to chiefs are made through the Lands Department.

The CCF has wide powers exercised through his subordinates. He lays down conditions, limitations and restrictions on timber trees, and his subordinates (Forest Officers) have powers of arrest without warrant. Some of these subordinates (Conservators of Forests) have powers to compound forest offences and to impose fines.

Forest Laws have been enacted to give legal effect to newly created reserves, to control entry into forest reserves, to control the minimum girth limits of merchantable trees, the amount of royalties payable for different species, inspection of export logs, and so on.

Difficulties have arisen in the practical implementation of these laws: Many of the laws are obsolete, and fines considered effective in the 1930s when some of the laws were passed are still being imposed in the 1970s. Some of the laws contain references to authorities that no longer exist. Amendments made to certain laws may not be readily available and both the amendments and the original laws continue to be applied, and a considerable confusion has arisen under such circumstances.

For political expediency certain powers of the CCF have been usurped by higher authority, The attitude of the public to forest offences is so apathetic as to make the forest officer a subject of ridicule by illegal timber producers who can afford to pay fines imposed by the courts and still make a profit from committing a forest offence. The sensitivity of governments to the destruction of food crop and cocoa farms illegally established in forest reserves acts as a stimulant to farmers to make further illegal clearings.

2.4 ECOLOGICAL CONDITIONS

2.4.1 The Major Vegetation Associations

The whole area of the GTHF has been sub-divided into four associations based on the floristic composition of the dominant trees (Taylor, 1952) as follows:

(i) Cynometra-Lophira-Tarrietia Association (CLTA) - Evergreen

(ii) Lophira-Triplochiton Association (LTA) - Semi-deciduous

(iii) Celtis-Triplochiton Association (CTA) - Semi-deciduous

(iv) Antiaris-Chlorophora Association (ACA) - Semi deciduous

No distinct lines of demarcation exist (Lines on the accompanying map 1 are only broadly illustrative of the vegetation distributions), but one association imperceptibly emerges as another fades out along tension belts.

The subjects dealt with under Ecological Conditions are the Climate, Geomorphic Base, Geology and Soils, Forest Communities, and general concepts of Environmental conditions. References have been made (where appropriate) under each of these subjects to the GTHF in general and their sub-divisions into associations. Table 1 provides a concise but simplified version of the major differences and similarities among the associations to enable quick references to be made:

TABLE 1 Floristic Associations in the Ghana Tropical High Forests (GTHF)

Main Features / Associations	Cynometra-Lophira-Tarrietia Association (CLTA)	Lophira-Triplochiton Association (LTA)	Celtis-Triplochiton Association (CTA)	Antiaris-Chlorophora Association (ACA)
Area	2905 sq. miles (743,680 ha.)	3245 sq. miles (830,720 ha.)	15,180 sq. miles (3,886,080 ha.)	10,430 sq. miles (2,670,080 ha.)
% of Area of GTHF taken up by the Association	9.15	10.22	47.80	32.84
A total Area of Forest Reserves in the Association	604.75 sq. miles (154,816 ha.)	566.84 sq. miles (145,110 ha.)	3,110.53 sq. miles (796,295 ha.)	1749 sq. miles (447,744 ha.)
Average Annual Relative Humidity %	80 - 83	76 - 77	47 - 77	40 - 77
Average Daily Temperature	75-80^{0}F (24-27^{0}C)	75-80^{0}F (24-27^{0}C)	75-85^{0}F (24-30^{0}C)	75-90^{0}F (24-32^{0}C)
Mean Annual Rainfall	84 ins (2140 mm)	64 ins (1627 mm)	60 ins (1545 mm)	52 ins (1330 mm)
Soils	Mainly Forest Oxysols These are orange brown to yellow brown kaolinitic clay. Surface soil reaction is 4.0-5.0 or lower. Reaction tends to be less acid with depth, pH rising to about 5.2 in the weathered substratum 6ft. below. Mn occurs erratically. Organic matter is a little less than in ochrosols, but	Forest Oxysol - Ochrosol Intergrades These soils are a transition between the oxysols and ochrosols. The pH may range from 4.0 to 6.0.	Mainly Forest Ochrosols - These soils are red, brown, or yellow, porous, thoroughly weathered soils sometimes containing iron-stone concretions or iron pan. They are less highly leached, but they are more productive than oxysols. The surface soil reaction is 5.5-7.0. The reaction tends to become more acidic with depth, the pH falling to 5.2 in the weathered substratum in some areas. The reaction of the weathered substratum tends to be similar to that of oxysols; this indicates that rainfall differences must account for the differences in topsoil reactions.	

TABLE 1 (Cont'd)

Main Features \ Associations	CLTA	LTA	CTA	ACA
Soils (Cont'd)	more spread down the profile, possibly due to increased leaching. Small amount of oxysol-ochrosol intergrades also occur.		Small bands of oxysol and oxysol-ochrosol intergrades also occur.	
Species	Cynometra ananta, Lophira alata, Tarrietia utilis are the typical species. Most species are evergreen; however, some of the upper canopy trees like Bombax, Ceiba and Khaya and Entandrophragma are deciduous; the deciduous trees are not confined to this association. Triplochiton scleroxylon is absent, so also is Entandrophragma utile. Evergreen species in the lower closed canopy are Cola chlamydantha,	Lophira alata and Triplochiton scleroxylon are not really at their optimum here but they occur as other species. The name given to the association is only descriptive. Tarrietia utilis is rare. Cola cordifolia, Pterygota macrocarpa, Sterculia rhinopetala begin to appear. Common meliaceace such as Entandrophragma cylindricum, E. angolense, Guarea cedrata, Khaya ivorensis, Lovoa trichilioides and common Leguminosae like Daniellia similis Destemonanthus benthamianus, Piptadeniastrum africanum all found in	Celtis soyauxii, C. zenkeri, C. adolfi-frederici, Triplochiton scleroxylon, Cylicodiscus gabunensis, and Piptadeniastrum africanum are very common. Lovoa trichilioides becomes rare. Khaya anthotheca occurs in the north-western part of the association. Entandrophragma utile appears for the first time. Evergreen species in the lower slightly more open canopy are Coynanthe pachyceras Monodora myristica, Myrianthus spp., Baphia nitida,	Antiaris africana, Chlorophora excelsa, Morus mesozygia, Nesogordonia papaverifera, Cola cordifolia, Mansonia altissima, Pterygota macrocarpa, Sterculia rhinopetala and Chrysophyllum spp. are well represented. Celtis and Triplochiton are not as common as in the Celtis-Triplochiton association. Khaya ivorensis is replaced by Khaya grandifoliola. Khaya anthotheca is found towards the northern end of this association where Piptadeniastrum africanum becomes infrequent. Pericopsis

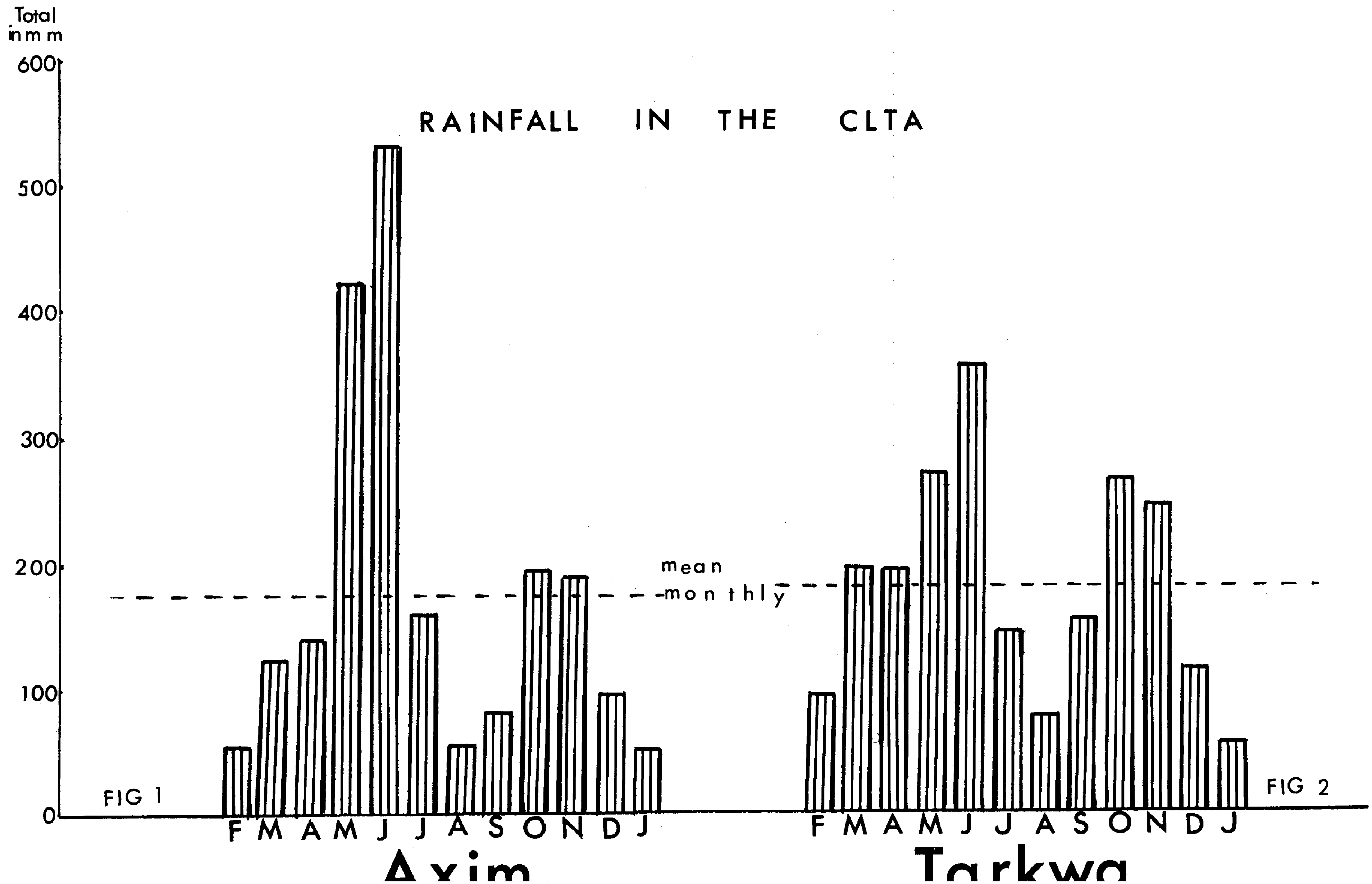
TABLE 1 (Cont'd)

Associations / Main Features	CLTA	LTA	CTA	ACA
Species (Cont'd)	Diospyros sanzaminika, Pentadesma butyraceae, Strombosia pustulata. The shrub layer contains Bertiera racemosa, Conopharyngia chippii, Randia hispida, Scaphopetalum amoenum (a scrambling shrub).	the Celtis-Triplochiton and Antiaris-Chlorophora associations are present in the emergent canopy. Evergreen species in the lower closed canopy are the same species represented in the lower closed canopy of CLTA except that Diospyros sanzaminika becomes rare.	Trichilia heudelotii, Aidia genipaeflora. Coffea spp., Vitex fosteri.	elata is common. Cylicodiscus gabunensis is absent in the northern and southern strips of this association. Lower storey species are the same as those of the CTA but in addition Childlovia sanguinea and Talbotiella gentii occur.
	The ground flora found in the CTA and ACA are also found here. In addition the branching fern (Gleichenia linearis) and horn moss (Lycopodium cersum) are found especially alongside roads.		Common ground flora are Leptasis cochleata, Aframomum spp., Maranthochloea spp., Dracaenia spp., Palisota bracteosa, Penianthus patuliaeris, some species of gramineae, and runners like Smilax kraussiana.	

(Source: Derived from Vegetation Zones of the Gold Coast, by Taylor)

TOWN	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	PERIOD
	CYNOMETRA – LOPHIRA TARRIETIA ASSOCIATION													
Axim	51.56	56.64	124.71	140.21	420.12	530.61	159.77	56.39	82.30	194.06	189.99	97.03	2103.39	37 Yrs.
Tarkwa	55.63	95.50	197.87	196.09	271.27	355.85	145.54	79.25	155.70	263.14	245.36	114.55	2175.75	20
Av.	53.60	76.07	161.29	168.15	345.70	443.23	152.66	61.82	119.00	228.60	217.68	105.79	2139.59	
	LOPHIRA – TRIPLOCHITON ASSOCIATION													
Bondaye	44.96	83.06	164.85	144.02	227.33	259.84	116.84	55.88	122.43	214.63	177.04	82.55	1693.43	20
Enchi	47.24	63.50	125.48	138.18	207.01	247.40	143.26	76.20	153.92	209.80	104.65	44.45	1561.09	
Av.	46.10	73.28	145.17	141.10	217.17	253.62	130.05	66.04	138.18	212.22	140.85	63.50	1627.26	
	CELTIS – TRIPLOCHITON ASSOCIATION													
Kumasi	18.29	58.67	138.43	142.49	190.50	221.23	128.52	74.93	180.85	200.15	97.79	28.96	1480.81	46
Obuasi	21.59	72.39	147.07	156.72	219.46	215.65	165.86	86.61	159.00	223.01	142.24	50.55	1660.15	16
Bibiani	15.24	60.45	127.25	128.02	220.73	228.60	137.16	85.09	167.39	195.58	92.46	37.08	1495.05	16
Av.	18.37	63.84	137.58	142.41	210.23	221.83	143.85	82.21	169.08	206.25	110.83	38.86	1545.34	
	ANTIARIS – CHLOROPHORA ASSOCIATION													
D'Ahenkro	11.94	60.96	93.73	136.40	168.91	183.39	92.46	43.94	102.11	189.69	43.94	22.61	1147.08	
Ho	37.34	72.64	138.94	140.72	170.18	180.34	127.76	87.88	155.45	181.61	78.49	46.74	1418.09	29
Wenchi	5.84	44.96	87.38	143.76	169.42	208.53	87.12	69.34	192.79	216.66	75.18	19.56	1320.54	28
Goaso	14.48	47.75	118.36	156.46	195.33	234.70	136.91	99.82	190.75	233.17	94.23	16.51	1438.65	
Av.	17.40	56.58	109.60	144.34	175.96	201.74	111.06	75.25	160.28	204.53	72.96	26.36	1331.09	

(Source: Working Plan Records, Forestry Department, Ghana)


RAINFALL IN THE CLTA
Total in mm
600
500
400
300
200
100
0
mean monthly
FIG 1
FIG 2
F M A M J J A S O N D J
F M A M J J A S O N D J
Axim
Tarkwa

RAINFALL IN THE LTA

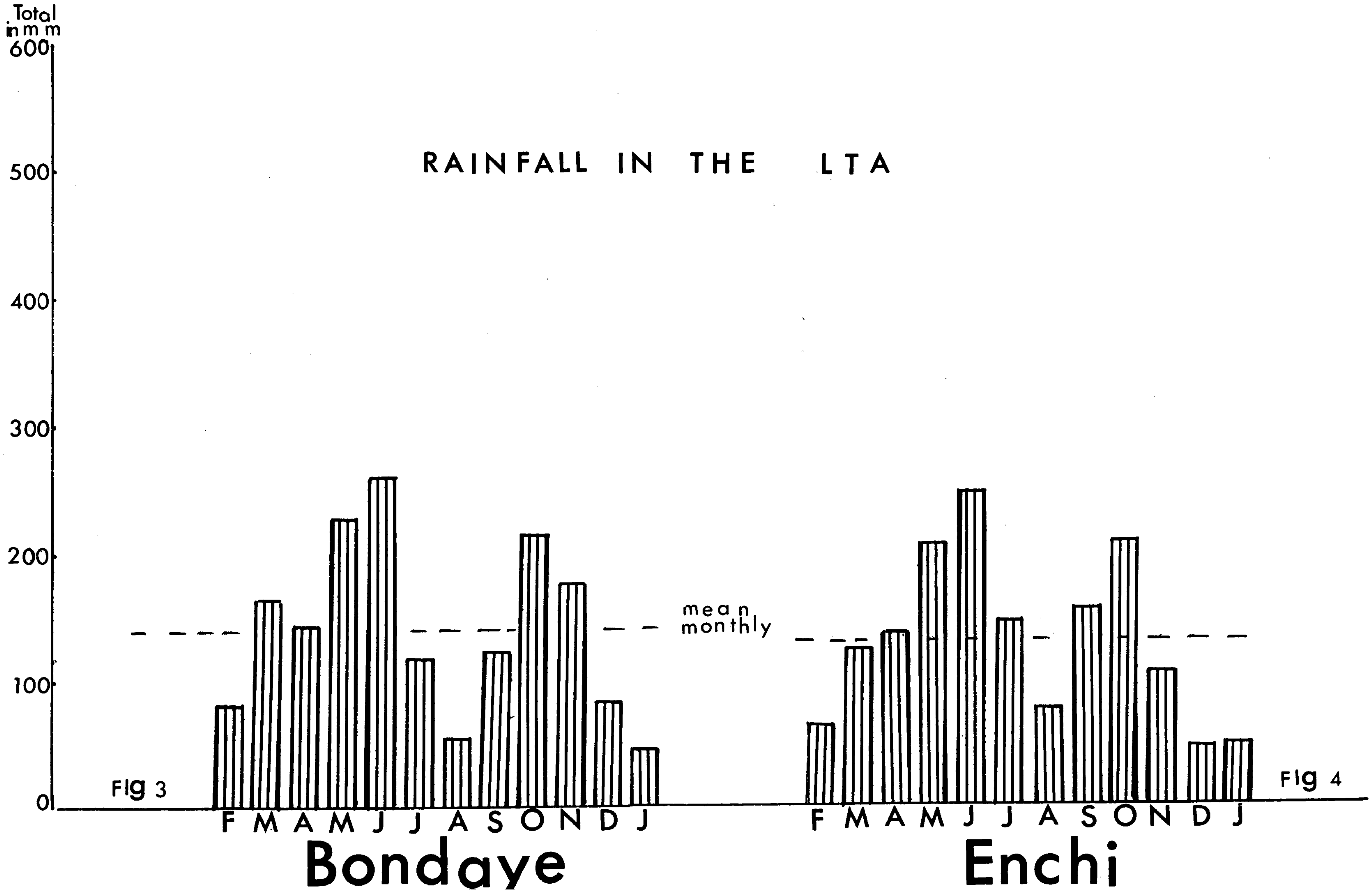
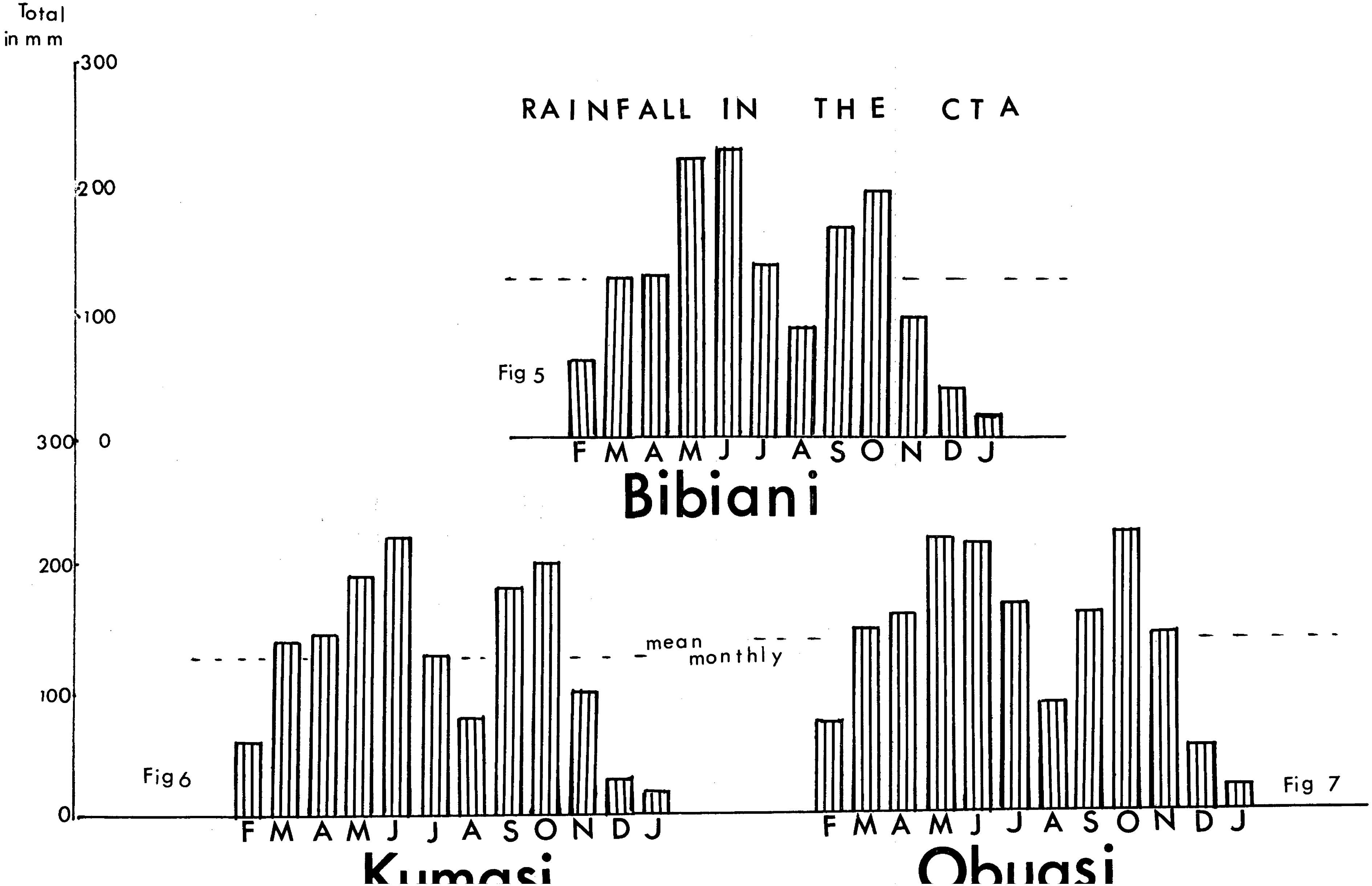


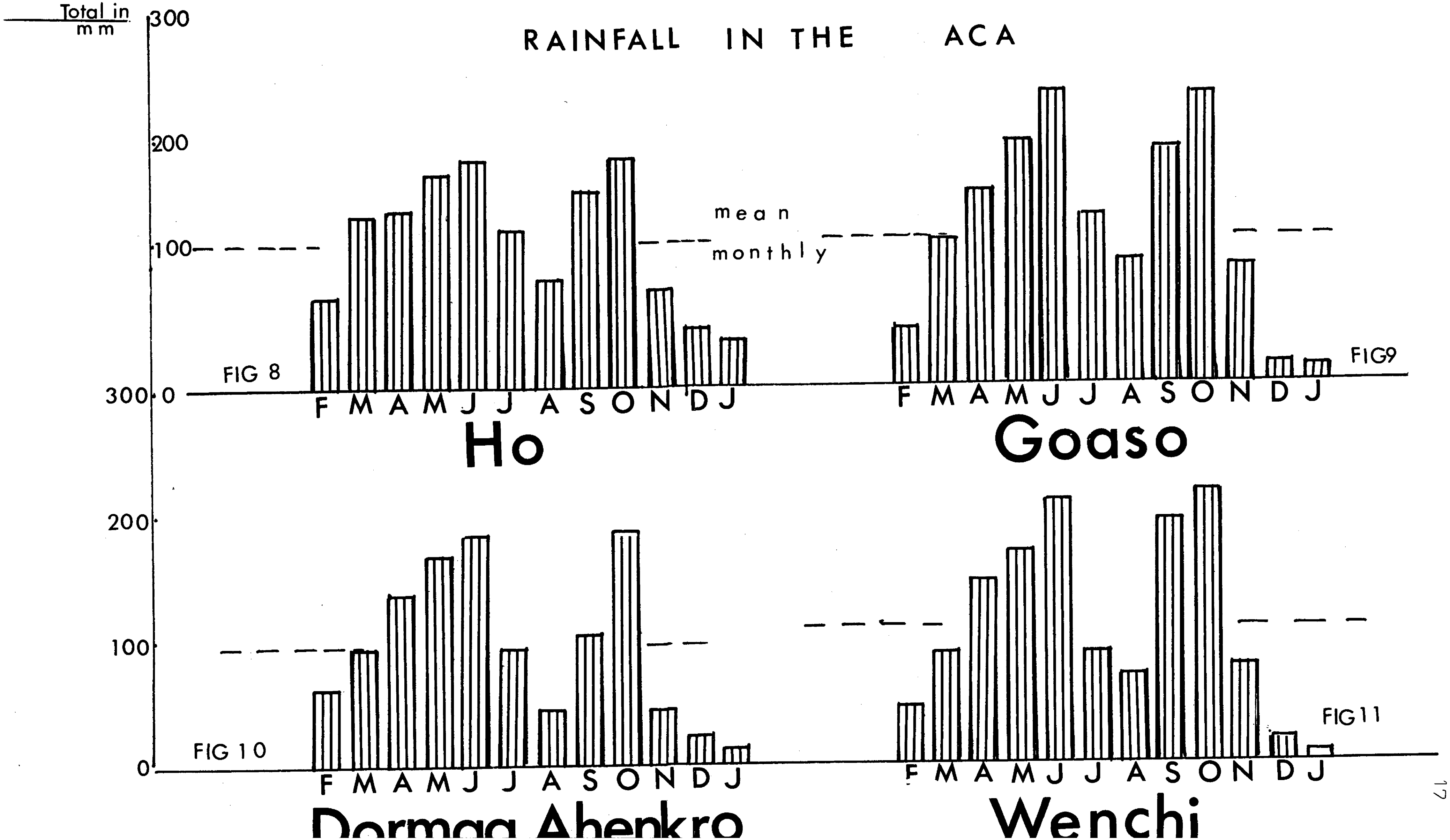
Fig 3

Fig 4

RAINFALL IN THE CTA



RAINFALL IN THE ACA



2.4.2 Climate

2.4.2.1 Wind Movements and Rainfall

The general climate of Ghana is influenced by the seasonal movements of the inter-tropical convergence zone (and its daily fluctu- ations) formed by the south-west monsoon winds from the Atlantic Ocean and the north-east trade winds from North Africa, at their points of convergence. The location of this buffer zone at any one time depends on the relative strengths of both wind movements.

Wet conditions are experienced south of the zone and dry conditions prevail north of it.

The rainfall year begins in February and ends in January. A gradual rise in the monthly rainfall reaches its peak in June (Table 2 and Figures 1-11). This is followed by a sharp drop in rainfall in July which continues into August when the rainfall may drop to about the February average. Cool, cloudy, dry but humid conditions prevail in August. The rainfall rises again in September and reaches a second but lower peak in October. Thereafter the desiccating and debilitating harmattan winds begin to be felt. The rainfall decreases from November to January when the lowest rainfall is recorded.

The rainfall pattern described above is the same throughout the GTHF, but the amounts of precipitation in any one month varies from one association to another (as illustrated in Figures 1-11).

Rainfalls are fairly well distributed throughout the month in the CLTA; there is a gradual decrease in the number of rainy days towards the ACA. The differences in volume and periodic distribution of rainfall have some effects on soils, species composition and phenological behaviour of trees in different associations.

TABLE 3 Relative Humidities per cent from Selected Areas in the GTHF

Town	Association	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean Annual	Period of Recording
Tarkwa	CLTA	82.00	79.95	80.78	80.00	83.13	83.37	80.33	80.38	80.02	80.83	80.20	80.12	80.90	20 Yrs
Bondaye	LTA	76.00	77.60	79.10	80.00	79.60	77.60	76.40	76.00	76.00	78.30	77.50	79.90	77.83	20 Yrs
Kumasi	CTA	47.00	48.00	54.00	62.00	64.00	70.00	74.00	74.00	74.00	67.00	63.00	58.00	63.08	46 Yrs

(Source: Working Plan Records of the Forestry Department, Ghana)

2.4.2.2 Relative Humidity

In general high humidities are experienced (Table 3). In the CLTA and LTA relative humidities appear to be unaffected to any significant degree by the dry harmattan winds probably because of the gradual weakening in strength as well as a steady increase in moisture content of these winds as they move towards the south-western part of Ghana. Alternatively, in the CTA and ACA the harmattan winds are strong enough to reduce relative humidity, especially during November to March.

Phenological behaviour of many trees in these associations appears to be associated with seasonal changes in humidity. Fruiting and leaf-fall of deciduous trees may take place in November - March, and foliage appears and persists in April - October.

2.4.3 The Geomorphic Base

Two main plateaux, both associated with the ACA, are the most distinctive features of Ghana's geomorphology (Map 2). One plateau runs from north to south along longitude $o^{0}30'$ east and lies between latitudes $6^{0}30'$ and $8^{0}30'$ north; it attains a maximum altitude of 2832 ft. (863m.). The other plateau lies in the south-east north-west direction between latitudes $5^{0}30'$ and 8^{0} north and longitudes $0^{0}30'$ and $2^{0}30'$ west; it attains a maximum altitude of 2586 ft (788m.). Below this plateau lies the bulk of the GTHF which also contains a series of hills dissected by rivers flowing southwards into the sea. Above this plateau again lies the tension belt between the GTHF and the Guinea Savanna Woodland (GSW). Among the important rivers flowing within the

GTHF are the Tano, Ofin, Ankobra, Pra and Densu. The only inland lake, Bosomtwe, lies in a trough 19 miles from Kumasi, and it covers an area of some 20 sq. miles.

Panoramic, features, enclosed and canopied (viewed from underneath a closed forest) landscapes are common and make scenic viewing a real joy.

TABLE 4 Rock Formations in the GTHF (Source: Map 3)

Formation	Rock and Mineral Constituents	Distribution
Lower Birrimian	Phyllites, schists, tuffs greywackes	Found in all four associations
Upper Birrimian	Metamorphosed Lavas, pyroclatic rocks, hypabyssal basic intrusive rocks, schists, greywackes.	" "
Tarkwaian	Quartzites, phyllites, grits, conglomerates, schists.	" "
Granite	Pegmatites, biotite, schists, porphyry, gneiss, undifferentiated granites.	" "
Basic Intrusive	Gabbro, dolerite, epidiorite, serpentine.	
Eocene and Cretaceous	Shales, sandstones, limestones	Found in CLTA
Voltaian Sandstone	Sandstones	CTA
Volcanic	Volcanic tuffs, jaspers, calcareous, arenaceous and ferrugineous shales, sandstone, greywackes.	CTA

2.4.4 Geology and Soils

2.4.4.1 Geological Formations

The GTHF are generally underlain by Lower Birrimian formation (Ghanaian classification) the continuity of which is broken at intervals by Upper Birrimian and Tarkwaian formations, running in the north-east south-west direction, and also be scattered granite formations the largest of which lies in the CTA (Map 3). Alwo within the Tarkwaian formation are small bands of basic intrusive formation. Few localised formations also occur. These are the Eocene and Cretaceous formations in the CLTA, Voltaian sandstone and volcanic formations in the ACA.

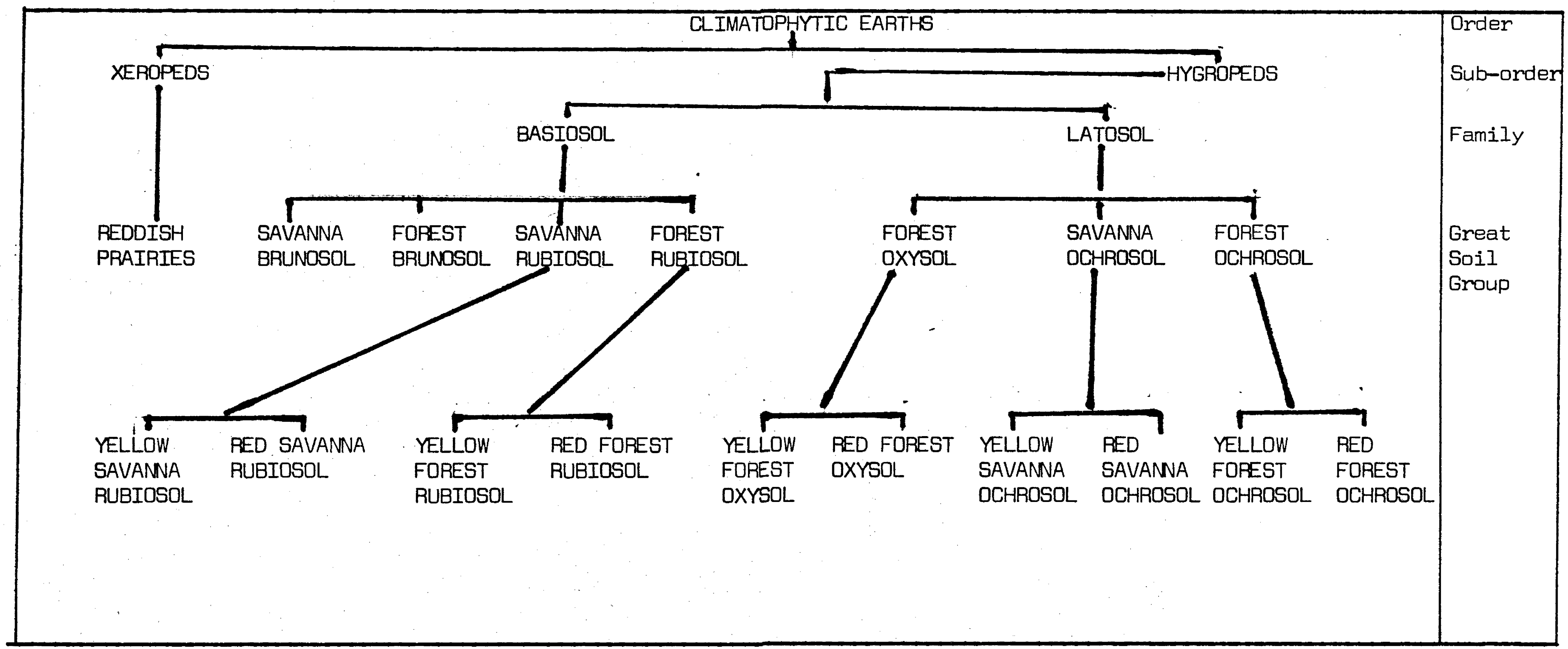
The rock and mineral constituents (Table 4) support the lush vegetation of the GTHF; the main formations are generally common to all the four vegetation associations and hence may not be significant in determining differences in species composition in the associations.

2.4.4.2 Minerals

Four minerals, in order of their current economic importance to Ghana, are gold, diamond, manganese and bauxite (Maps 2 and 3). All four minerals occur in the area of the GTHF in Birrimian, Tarkwaian and Cape Coast Granite Formations, and all of them are mined using sophisticated modern technology.

In addition diamond prospecting is undertaken by many individuals using cumbersome and rather primitive methods.

TABLE 5 Classification of Climatophtic Earths



(Source: Mohr, Tropical Soils)

2.4.4.3 Soils

The forest soils of Ghana documented in Table 1 have been formed largely under moist tropical climatic conditions and therefore can be classified as Latosols (Table 5). Latosols include deeply weathered, highly leached soils with largely kaolinitic clay mineral content and low cation exchange capacity, and they are well distributed in the GTHF (Map 4).

The soils of the CLTA are mainly oxysols; those of the LTA are almost entirely oxysol-chrosol intergrades, while the soils of the ACA and CTA are generally forest ochrosols but with bands of oxysol-ochrosol intergrades, rubrisol-ochrosol intergrades and oxysols. The characteristics of oxysols and ochrosols (Table 1) and the differences between them appear to be mainly the surface soil reaction and moisture content. Where there is greater rainfall which is also evenly distributed, oxysols with the more acid surface soil reaction, are formed. As the amount of rainfall decreases and its distribution becomes less regular, ochrosols, with less acid surface soil reaction, are formed. The amount and distribution of rainfall and its effects on soil acidity may contribute to vegetation differentiation in the GTHF. The ochrosols cover a wider area than the oxysols, and the presence of different associations on them may be the result of seasonal variations in moisture content of the soil, resulting from variations in the number of rainy days during the month, and the monthly and annual mean rainfalls.

The latosols have developed on drift, sedentary, colluvial and alluvial parent soils the nature of which may be as an important factor as the climatic effect on the soils. General descriptions of these parent soils (Ahn, 1959) have been therefore given below to indicate their importance in the formation of latosols:

Drift Soils

The drift soils are reddish to brown clay loams 3-5m. deep and found on flattish summits where they have been built up through hill-wash and soil creep. Their formation is probably associated with cyclical geological erosion. They are usually fine textured with a predominant clay content and cuboidal or platy structure, hard consistency and high water retaining capacity. They are often underlain with a zone of 25-75cm. thickness containing iron concretions, quartz gravel and an iron pan below which lies the weathered parent rock.

When drift soils are washed by sheet erosion the iron concretions below harden into solid impenetrable laterites.

Drift soils are generally devoid of weatherable minerals and have very low nutrient content. They may be well aerated and penetrable by roots although they can become hard in the dry season.

Sedentary Soils

Sedentary soils usually lie on upper and lower slopes between the drift soils of the flattened summits and the colluvial soils of the lower slopes; they can be divided into different groups according to the nature of the parent rock which may be igneous, sedimentary or metamorphic.

Sedentary soils derived from igneous granites, diorites, felspars, biotite, hornblende weather to relase potassium, magnesium and calcium. Such soils may be found in areas covered by Dixcove and Cape Coast granite complexes which are well scattered throughout the GTHF (Map 3). They may be dark or light brown in colour, finely textured, crumby in structure, of loose consistency, well drained and with a reasonably good water holding capacity.

The sedentary soils derived from sedimentary sandstone rocks, quartsites and shales of the plateau separating the GTHF from the GSW are light brown, coarse textured and very porous soils of low water holding capacity and poor nutrient status. They may be characteristic of more rugged and undulating country; they are also well aerated and penetrable by roots but they can be shallow with a depth of 1-2m.

Finally the sedentary soils derived from metamorphic phyllits and schists of the Lower Birrimian formation are the most extensive soils in the GTHF.

They are silty in texture, crumby in structure, of loose consistency, well drained, moderately deep (1-3 m.), easily penetrable by roots but impervious at moderate depths. Although they are generally good soils they may contain a high proportion of quartz and may sometimes be of low fertility status and of low moisture retaining capacity.

Colluvial Soils

Colluvial soils consist of 60-120 cm. of dark brown, finely textured soil, block-like in structure, with medium to hard consistency and free of stones and gravel, and lying over a sedentary weathered substratum. They occur on lower slopes below sedentary soils but above alluvial soils. Drainage conditions are not very good, and nutrient status is low. Colluvial soils are widely distributed in the GTHF, but they are not extensive in any one area in the GTHF.

TABLE 6 Parent Soil Capability Classes Based on Cocoa Production

Parent Soil	Parent Rock Formation	Productive Capacity in Dry Weight of Cocoa per Hectare per Annum	Distribution
Sedentary	Granite Complexes	1350 - 1700 Kg	Extensive in GTHF
Sedentary	Phyllites, tuffs, greywackes, schists (Birrimiam formation)	850 Kg	" "
Drift	Eroded materials of various formations	775 Kg	Limited occurrence
Alluvial and Colluvial	" " "	Below 775 Kg	Widely distributed but not extensive in any one area

(Source: AHN, Soil/Vegetation relationships, Ghana)

Alluvial Soils

Alluvial soils are usually grey to yellow-brown or dark coloured soils of coarse to fine texture, loose to hard consistency and mottled in the lower horizons. Under poor drainage conditions the sub-soil is grey coloured. Many soils of valley bottoms and river flats are of this type.

Soils in General

Parent soils in the GTHF have been classified by the Ghana Ministry of Agriculture on the basis of their ability to support cocoa farms for long periods of say 20-50 years without manuring (Table 6).

According to this classification the fertility of any particular soil in the GTHF (whether the soil belongs to the oxysol, ochrosol, or oxysol-ochrosol intergrade group) is greatly determined by the nature of the parent soil material. A careful scrutiny of Maps 1 - 4 reveals that some of the forest reserves in the GTHF are associated with the best soils in the country.

TABLE 7 List of Species of Economic Importance and their Uses

No.	Botanical Name and Symbol used in Table 11	Trade Name	Economic Class	Uses
1	Chlorophora excelsa (C)	Iroko or Odum	Ia	General construction, interior fittings, wagonbody, flooring piling, containers of radioactive material.
2	Entandrophragma angolense (E)	Edinam	Ia	Panelling, bank fittings, high class furniture, decorative veneer, ship-building, motor body, interior joinery.
3	Entandrophragma cylindricum (Y)	Sapele	Ia	Furniture, panelling, railway coaches, ships' saloons, decorative veneer, interior joinery.
4	Entandrophragma utile (U)	Utile	Ia	Interior furniture, ships interiors, lorry bodies, door frames interior joinery, fittings, decorative veneer.
5	Khaya anthotheca (K)	Anthotheca	Ia	Furniture, panelling, interior joinery, decorative veneer.
6	Khaya grandifoliola	Mahogany	Ia	Counter tops, block flooring.
7	Khaya ivorensis	African mahogany	Ia	Panelling, furniture, interior fittings in ships' and coaches.
8	Mimusops djave (H)	Makore	Ia	General construction, furniture, decorative veneers, laboratory benches, sleepers.
9	Nauclea diderrichii	Kusia or Opepe	Ia	Piles for harbour work, mines, flooring, railway wagon bottoms, boat planking, mortars.
10	Pericopsis elata	Kokrodua	Ib	Substitute for teak in ships' decking and railings, high class furniture, flooring, sleepers.
11	Lovoa trichilioides (L)	African walnut	Ib	Furniture and panelling, cabinet work, decorative veneer.

TABLE 7 (Cont'd)

No.	Botanical Name and Symbol used in Table 11	Trade Name	Economic Class	Uses
12	Terminalia ivorensis (I)	Emeri or Idigbo	Ib	General utility and construction, high class joinery, veneer, lorry bodies, roof shingles, sleepers.
13	Triplochiton scleroxylon (T)	Obeche or Wawa	Ib	General utility, construction work, core for blockboard or plywood, dugout canoes.
14	Tarrietia utilis	Nyankom	Ic	Mine sleepers, furniture, joinery, boat building, greenhouses.
15	Entandrophragma candollei (D)	Candollei	IIa	High class joinery, flooring, furniture, cabinet work.
16	Guarea cedrata (G)	Kwabohoro	IIa	Furniture, interior fittings, high class joinery, panelling, boat building, veneer-substitute for mahogany.
17	Guarea thompsonii (R)	Guarea	IIa	Furniture, flooring, plywood.
18	Lophira alata	Kaku or Ekki	IIa	Mine shaft guides, switchboards (high electrical resistance), stairways, heavy duty flooring, piles, piers, jetties.
19	Piptadeniastrum africanum (P)	Dahoma	IIa	Mine and railway sleepers, substitute for Odum, bridges.
20	Antiaris africana (A)	Antiaris or Kyenkyen	IIb	Cutlass handles, boxes, benches, canoes, plywood core, light joinery.
21	Guibourtia ehie	Hyedua or Bubinga	IIb	Furniture, panels, counter tops, knife handles, guitars.

TABLE 7 (Cont'd)

No.	Botanical Name and Symbol used in Table 11	Trade Name	Economic Class	Uses
22	Mansonia altissima (M)	Mansonia	IIb	Window edges, dash boards of motors, high class furniture, piano cases, camera bodies, veneer.
23	Mitragyna stipulosa	Abura or Subaha	IIb	General utility, plywood, doors, mouldings, carving, planking, flooring.
24	Nesogordonia papaverifera (N)	Danta	IIb	Wagon bodies, railway carriers.
25	Turreanthus africanus (F)	Avodire	IIb	Plywood, railway coach panelling, high grade panelling.
26	Cylicodiscus gabunensis	Okan or Denya	III	Heavy construction, sleepers, wharf decking, substitute for greenheart.
27	Distemonanthus benthamianus	Ayan or Bonsamdua	III	General utility, cabinet, ships' fittings, floors, staircases, veneer.
28	Afzelia africana	Afzelia	III	Superior joinery such as staircases, panelled doors, countertops harbour work, sleepers, substitute for teak.
29	Ceiba pentandra	Ceiba	III	Plywood core, insulation boards.
30	Pterygota macrocarpa	Kyere	III	Interior joinery, furniture, coffins, toys, wagon and carriage building.
31	Morus mezozygia	Wonton	III	Beams, mortars, firewood.
32	Anopyxis klaineana	Kokoti	III	Railway sleepers.
33	Diospyros spp.	Ebony	III	Turney, toys, fancy work.

2.4.5 Forest Communities

2.4.5.1 General Characteristics

The GTHF are climatic climax forests carrying many hundreds of different species. Although some 360 species among them can grow to timber size, only 25 species are currently considered of economic importance. These are the classes I and II species (Table 7) which will be referred to as Economic species. Of the two classes, Class I species are the more valuable economically. Other species not currently considered as important as those in classes I and II are grouped in classes III (some quoted in Table 7) and IV.

Economic species have again been grouped as classes Ia, Ib, IIa and IIb on the basis of similarities in growth rates, to facilitate yield calculations.

The distribution of the different species in the GTHF appears to depend on habitat suitability, species characteristics and pure chance. At close quarters sections of forest at various stages of seral development towards the climatic climax forest can be observed; it can also be noticed that other sections are held under edaphic subclimax, for example, sections carrying species of palmae such as *Ancistrophyllum* and *Calamus* spp. which form the raw materials for some cottage industries. Other important characteristics of the GTHF have been drawn from tabulated data collected from different methods of studying the high forests. The descriptions of the methods of study (sub-section 2.4.5.2) precede the presentation of the data (sub-sections 2.4.5.3, 2.4.5.4 and 2.4.5.5).

2.4.5.2 Methods of Studying the GTHF

Some of the important characteristics of the GTHF can be illustrated by tabulated data from (i) a 5% enumeration survey of Working Plan (WP) areas amd also (ii) analysis of growth of 898 desirable economic trees of various girth classes.

Both methods of study have been described below:

5% Enumeration Survey

This enumeration survey is undertaken in every working plan area. The office work prior to the survey includes the division of the productive part of the working plan areas into strata according to the major vegetation associations (Table 1) and density of stocking. This is done, where applicable, to increase the precision of the sampling.

The strata are shown on a map on a scale of 1 : 12,500.

Each stratum is systematically divided into 40 ch. x 80 ch. (805 m. x 1610 m.) blocks which should as much as possible lie across the direction of drainage. That is, the 80 chain length of the block lies across the direction of drainage. The length of the block is, in effect, predetermined to take account of as much of the local variations as possible. Two sample strips to be enumerated in each block are selected at random using a table of random numbers. Each block is first placed on a grid paper numbered in rows and columns. Then a random number of say 0547 is selected and if some of the numbers in rows (say 05) and columns (say 47) make up the selected random number, then the intersection of the particular rows and columns chosen gives the starting point of the sample. Each sample strip is 1 ch. x 80 and lies on either side of the centre line cut from the starting point. The total area of the two sample strips is approximately 5% of the area of the block.

This method of sampling is a Two-stage sampling process, the first stage being the location of the starting point and the second stage being the enumeration of two contiguous strips once the starting point is located (Freese, 1962).

After the stratification, the division of strata into blocks, and the selection of starting points of the sample strips, a schedule is prepared on magnetic north bearings to show the tie-lines for locating the strips on the ground. All this is done in the office.

The actual field work involves using the hand-oil compass and chain to locate the starting point and for cutting the centre line. Posts are erected at 2.5 ch. (50.29 m.) intervals along the centre line. On either side of each post is an offset at right angles to the centre line to mark the width of each strip. All survey data within each 2.5 ch. x 1 ch. on either side of the centre line are recorded before the survey party moves into the next 2.5 chain sub-strip.

Within each strip girths of trees are measured with the girth tape at breast height or with the tangent stick (modification of the Baltimore Stick) at 1 ft above the convergence of the buttress.

All girths of trees between 1 ft and 3 ft (30.48 cm. and 91.44 cm.) are recorded in 1 ft girth classes for all classes I and II species individually, and for the total number of other species in each girth class. All girths of trees between 3 ft and 5 ft (91.44 cm. to 152.4 cm.) and between 5 ft and 15 ft (152.4 cm. to 457.2 cm.) are recorded in 1 ft and 2 ft girth classes respectively for all classes I to III species individually, and for all other species as a group for each girth class.

Sixteen samples of 256 acres (102.4 ha.) are normally completed monthly at the cost of 1.1 man days per acre (2.75 man days per hectare).

The enumeration records are summarised by species and girth classes for classes I and II species and all other species as a group by girth classes. From the records the Reliable Minimum Estimate (RME), representing the lower limit of the confidence interval, is calculated by species and girth classes at a 90% probability level (the probability was originally found from 12 Forest Reserves using 16 acre sample strips).

The RME's are very conservative figures and they represent the minimum estimated stocking in a complex community with wide variations of stocking density and girth classes, even within a stratum. The data for the 5% enumeration surveys and inferences drawn from them appear in sub-section 2.4.5.3.

The Permanent Sample Plots

Some of the conclusions for this study have also been drawn from thirty Permanent Sample Plots (PSP) in Bobiri Forest Reserve. These plots form part of a series of PSP that have been established in several forest reserves in the GTHF since 1969, or the initiative of Mr J.F. Baidoo, the then Conservator of Forests, in charge of the Working Plans Branch.

The PSP are expected to yield accurate information on growth performance of economic species as well as the effects of some of the factors affecting growth.

TABLE 8 Stocking per Hectare of All Species 1ft Girth+

Association	GIRTH CLASSES								Total	Actual Area 5% Enumerated in Ha.
	1-3ft	3-5ft	5-7ft	7-9ft	9-11ft	11-13ft	13-15ft	15ft		
	30.48-91.44 cm	91.44-152.4 cm	152.4-213.36 cm	213.36 - 274.32 cm	274.32-335.28 cm	335.28-396.24 cm	396.24-457.20 cm	457.20-cm+		
CLTA	292.50	82.88	13.85	5.8	2.5	0.7	0.2	0.1	398.53	1241
LTA	333.5	73.9	14.98	6.65	3.1	1.4	0.63	0.50	434.66	2528
CTA	276.25	63.35	15.6	7.88	4.05	2.0	0.95	0.88	370.96	1932
ADA	333.5	74.5	19.38	9.13	3.88	1.63	0.88	0.55	443.45	768
TOTAL	1235.75	294.63	63.81	29.46	13.53	5.73	2.66	2.03	1647.60	-
MEAN	308.94 ± 30.8	73.66 ± 8.01	15.95 ± 2.4	7.37 ±1.45	3.38 ±0.71	1.43 ±0.54	0.665 ± .38	.51 ± .32	-	-

(Source: W.P. Branch Records, Forestry Department, Ghana)

The productive part of a Working Plan area is divided into square mile blocks within each of which two plots (each measuring 5 ch. x 5 ch.) are randomly selected. Each plot is sub-divided into twenty-five 0.1 acre (0.04 ha.) sub-plots. Wherever possible, 2 potential sawlog trees at the sapling and pole stages, as well as currently merchantable trees, all of economic species, have been marked on each sub-plot. The girths of the marked trees have been measured annually at breast height or above the convergence of the buttress. The sample plots have generally been established in productive areas in which selective felling has taken place in the past. From the thirty plots in Bobiri Forest Reserve (CTA), 898 trees were measured in the 2-year period between 1969 and 1972, and the data collected from these thirty plots as well as the inferences drawn from them have been presented in sub-sections 2.4.5.4 and 2.4.5.5.

2.4.5.3 Some Characteristics of the GTHF Based on RME from 5% Enumeration Surveys

The conclusions drawn from this sub-section are based on RME for -

(i) Density of Tree Stocking (all spp.);

(ii) Density of Stocking (Economic spp.); and

(iii) Density of Stocking (Economic species from Selected WP areas).

Density of Tree Stocking (All Species)

The calculated RME for all species 1ft girth and above (Table 8) provide some interesting information about the GTHF. About 72-78% of the total stocking is found in the 1ft - 3 ft girths, and

90 – 95% in the 1 ft – 5 ft girths. The average spacing of trees in the 1 ft – 5 ft girths is about 16 ft (4.9 m.) which may be sufficient to maintain a closed canopy even without the emergent trees (5 ft girth and above) which form 5–10% of the total stocking. These few emergent trees, however, account for 35–45% of the total standing basal area and support such large and heavy crowns that they must of necessity stand well above the general canopy in order to obtain sufficient solar energy and at the same time ensure that some of this energy is made available to those trees immediately below them. The general structural arrangement of the forest in tiers, the presence of tall cylindrical boles and the supporting plank buttresses of the emergent trees do not therefore appear to arise by accident. The greater the girth class of the emergent trees the smaller the number of trees present in that particular girth class. The large trees occupy more space and perhaps utilize more soil nutrients; restriction of their number is therefore necessary for the achievement of diversity required for the maintenance of stability.

The CLTA supports the smallest basal area of about 236 hoppus sq. ft. (22 m^2) per hectare and has the smallest number of emergent trees; the ACA and the CTA generally support a basal area of about 270–300 hoppus sq. ft. (25–28m^2), and the LTA supports a slightly lower basal area per hectare. The LTA, CTA and ACA have a considerably greater number of emergent trees than the CLTA. The evergreen nature of the latter helps to maintain a permanent and denser closed canopy which apparently does not leave much room for the development of many emergents. The high concentration of trees in the 1 – 5 ft girth classes in this association is adequate to ensure strong competition and to prevent some young saplings of emergents among them from growing beyond the sapling stage. Many potential emergents may be held in check consistent with the development and maintenance of an optimum basal area within that association and habitat conditions. It is also possible that the large number of trees in the 1-5ft classes may exert strong competition on mature emergents, perhaps in nutrient uptake, thus preventing many such emergents from growing beyond a certain girth class before they die.

Mervart (Mervart, 1972) working in Nigeria found that trees in the medium girth classes have less mortality than trees in either the upper or lower girth classes, particularly in the latter, and that fast growing trees seem to have slightly lower cumulative mortality than slow growing species.

This suggests that once trees attain fast growth, especially in the medium girth classes, the competitive effects of the larger emergents and smaller girth classes are not strong enough to prevent the fast growth being maintained. When the build-up in species density reaches some optimum basal area, further increases in basal area resulting from fast growth may be counterbalanced by mortality in both the smaller and larger sizes, especially in the former, in which growth is slow. It also explains why the proportion of some emergents (especially economic species), which are capable of attaining fast growth in the medium girth classes, increases towards the larger girth classes.

TABLE 9 Stocking of Economic Species per Hectare

Association	CLTA 2060Ha. Enumerated			CTA 15329 Ha. Enumerated		
Economic Class	CLASSES I & II			CLASSES I & II		
Girth Classes in ft	No. of Trees	No. as % of Econ. Class Stocking	No as % of All Species Stocking	No. of Trees	No. as % of Econ. Class Stocking	No. as of all Species Stockir
1 - 3	4.34	42.93	1.48	19.84	54.76	7.18
3 - 5	2.64	26.11	3.19	8.59	23.71	13.56
5 - 7	1.40	13.85	10.11	2.66	7.34	17.05
7 - 9	0.98	9.69	16.90	2.32	6.40	29.44
9 - 11	0.51	5.04	20.40	1.56	4.31	38.52
11 - 13	0.18	1.78	25.71	0.78	2.15	39.00
13 - 15	0.04	0.40	20.00	0.32	0.88	33.68
15 +	0.023	0.20	20.00	0.16	0.45	18.18
TOTAL	10.11	100.00		36.23	100.00	

(Source: W.P. Branch Records, Ghana)

Density of Stocking (All Economic Species)

The pattern of distribution of trees by girth classes for economic species is similar to that of the all-species stocking (Compare Tables 8 and 9) in that the concentration of species is mainly in the 1-5ft girths. The proportion of economic species in the 1-3ft girth class is a small percentage of that of the all-species stocking; it varies from about 1.5% in the CLTA to about 7% in the CTA. The numbers of trees by girth classes in the all-species category decreases sharply at first with increasing girth classes and then somewhat more steadily. Where economic species only are compared with other species the proportion of trees in each girth class increases steadily from the lowest girth class and reaches its peak in the 11-13ft girth class. Beyond this girth class the proportion of trees of economic species declines. Species such as Khaya ivorensis, Entandrophragma cylindricum and Triplochiton scleroxylon exhibit this characteristic very well. This tends to support the view that mortality increases in the higher girth classes as a result of strong competition from other trees in the community. It is not clear whether this strong competitive ability of other trees is facilitated by senescence of the dominant tree species (Annin-Bonsu, 1970) or by other factors.

Unlike Khaya ivorensis, Entandrophragma cylindricum and Triplochiton scleroxylon, Entandrophragma utile appears to withstand this type of competition more successfully in that its stocking density does not vary very much beyond the 11-13ft girth class.

In general the economic species represent about a quarter of the all-species stocking for higher girths between 5-7ft and 15ft+.

Density of Stocking (Economic Species from Selected Working Plan Areas)

In the foregone analyses, the data have been drawn from enumeration surveys over a large number of working plan areas. In this study the data have been drawn from enumerations in specific working plan areas in different associations to determine whether the conclusions drawn from the general surveys also apply to a specific survey.

The 5% enumeration data from specific working plan areas (Table 10) in different associations have a similar pattern of stocking by girth classes as those of the all-species stocking and the stocking of economic species in that over 70% of the total stocking is concentrated in the 1-5ft girths. This tends to indicate that the large concentration of trees in the smaller sizes is consistently repeated and this may hold good even for individual species.

However, the density of stocking of economic species in some working plan areas may be much better than that of the economic species in general (Table 9). For instance the density of stocking of economic trees in Bonsá Forest Reserve is more than twice that of the CLTA in general.

2.4.5.4 Some Characteristics of the GTHF as Revealed by Data from the PSP

Some general observations on ecological characteristics of the GTHF have been drawn from the summary of the 898 trees measured (Fig. 12 and Tables 11a and 11b) as follows: The 30 plots vary in numbers of economic species present and in their girth class distribution. Although selective felling has taken place in Bobiri Forest Reserve

TABLE 11a List of the 898 Economic Trees Enumerated.
(Each Letter Represents one Tree of a Particular Species)

Plot	GIRTH CLASSES IN FT									Total No. of Trees
	0 – 1	1 – 2	2 – 3	3 – 4	4 – 5	5 – 7	7 – 9	9–11	11–13	13+	
1	EEYKTT TDDGG GGGP	UUUKK GAP	CYKT TTGN	GA	TNA	TT	YN	K			41
2	EEEYY U	EEEEE ETGG NNM P	TNN NMP	N	TP	C	Y				30
3	EEUUUK GNF	DFF	TDD DFFF	TPF FFFF	FFF	GFFA M					34
4	KTGFF AA	YYTTT GF	YTTT TDG NNNF	EYY T	TN M	KTN NF	CA	Y			40
5	EDGFF FFFF	YDFF	ETD GGF P	EGN FFFF AP	FFF	TTTG FFP	TAP				42
6	KKFFFFF MMP	EEEI DFFFP	KHA	EEK KGF FF	FP	FF	YK TN	Y			39
7	ETDN F	EUTT IDDG P	EYL GA	KTT NNF FP	YD FP	YFFF FA			Y		38
8	EDDGG GGGFP	EEUK KTGN NF	EEEE TTDD GGNA	KT A	ETN N		T				40

TABLE 11a (Cont'd)

Plot	GIRTH CLASSES IN FT										Total No. of Trees
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 7	7 - 9	9-11	11-13	13+	
9	KKKTG GGGGR FFFFFFFAA	KNF F	GGF F	CTN NFF A	KF A	CFFF					41
10	EEKKKK KTGNNF A	EKKN A	GFA	KTT	K	TT	KKK T			T	32
11	EEEKTT GGNNNP	KGN	EEYG NNA		KT	G	K				26
12	YG	EYTG NNAP	TTTTI GN	YTT T	TTP	TP	TT				28
13	YUUUGNN	EGN	CTNN	EKT D	CTT	TTTG AA	T				28
14	TGGGGG GGGGGG GNNN	GNNN	EM P	YGG GGA M	YTG	EEYK	TP	T			40

TABLE 11b List of 898 Economic Trees Enumerated

Plot	GIRTH CLASSES IN FT										Total No. of Trees
	0 – 1	1 – 2	2 – 3	3 – 4	4 – 5	5 – 7	7 – 9	9–11	11–13	13+	
15	EGGGGGG NN	EUGG GGN	EYNN	GA	KP	T		Y			26
16	EEEEEKK KGGGGNN	EEEEY KLGPP	YTTT GNP	I	CG P	G	YP				38
17	CEGGGG	KKTT GNA	YYKK HTNP	TTTN M	PP	TTTT TG					34
18	EEEKG	NN	H	UTTT	KA	UT		T	Y		18
19	EGGGN FFFF	EEED NP	EEEE TTGGN NF	FF	EG	HAA	A				34
20	EKDGN FFFFFFFFFF	FFF	LRA P	YFFA	NFF F	FFFFF	FF	Y	Y		39
21	EEEKKD GGGGGRN FFF	EEKK HGFF	ERA			YF	FF				31
22	NN	CTT	EYKT TFF	TT		KTT TTTN	K	T			23

TABLE 11b (Cont'd)

Plot	GIRTH CLASSES IN FT										Total No. of Trees
	0 - 1	1 - 2	2 - 3	3 - 4	4 - 5	5 - 7	7 - 9	9-11	11-13	13+	
23	EKKA	EKKK A	EEKG GN	AA	KP	NM	K	A			23
24	K	KG	EKTA	K		KKKK K	U	K			15
25	YGGGGGGG GP	KTTG GNN	EKG N	G NNP	IN	EP	E				30
26	GGNNNA	TDG NP	GGGP P	GA	NNA P	APP	K	A			27
27	KD		YTD GA	HAA		UG					12
28	EG	YTN		ETG	T	TG					11
29	EN	YGN	CCE GGG	ETAP	E	E	CT	E			20
30	EEEEKGG AP	EDA	YKG GN	N							18
TOTAL	252	164	167	107	64	91	37	12	3	1	898

(See Table 7 for Names of Species with Symbols Shown Here) in the past yet it may be valid to state that for widely distributed species with wind-borne seeds such as Entandrophragma angolense, E. cylindricum, Khaya anthotheca, Triplochiton scleroxylon, Guarea cedrata and Nesogordonia papaverifera (represented as spp. "E", "Y", "K", "T", "G" and "N" respectively in Fig. 12 and Tables 11a and 11b) the presence of a young sapling or pole of a particular species in any one area does not necessarily mean that the mother tree is nearby. In the case of gregarious species such as Turreanthus africanus (represented as sp. "F" in Fig. 12 and Tables 11a and 11b), which also have drupaceous fruits containing substances poisonous to herbivores, the situation referred to above is uncommon.

Where there is a large concentration of a particular gregarious species there is a limitation imposed on the number of other species which can be present. This can

(i) result in the failure of the trees present in that particular area to fully utilize all the ecological niches and

(ii) limit to a certain extent the potential biomass production.

A further observation is that although a species may be widely distributed the extent of its occurrence seems to be influenced by the number of other species present and their stocking density. On the basis of the plot records, a suggestion (Jack, 1961) that Triplochiton scleroxylon does not seem to be affected by the presence of other species is questionable.

2.4.5.5 Growth of Economic Trees in the GTHF Based on Data from the PSP

The complex and relatively stable nature of the climatic climax community, with its built-in checks and balances (Table 15a), has posed problems about growth performance of individual species and girth classes.

To facilitate yield regulations for working plan areas (worked on a 25 year felling cycle), foresters in Ghana have had to accept rough estimates of growth of economic species in terms of Times of Passage (TOP) between one 2ft girth class and the next higher girth class, which may be the Minimum Exploitable Girth class (MEG). The TOP which were first calculated by Kinloch and Jack(both were in charge of Working Plans at different times), were based on girth increment sample plot figures for untreated forest. These increments (TOP) have been maintained over 30 years for class Ia trees between girth classes 7-9ft and 9-11ft, 22.5 years, 25 years, and 30 years for classes Ib, IIa and IIb trees respectively, between girth classes 5-7ft and 7-9ft. The TOP referred to above are equivalent to annual increases in basal areas of 69.68cm^2, 72.26cm^2, 65.03cm^2 and 54.19cm^2 for classes Ia, Ib, IIa and IIb trees respectively.

The preliminary results of the 30 plots in Bobiri Forest Reserve have been examined in this study to indicate the trends of actual growth rates, and also the effects of a number of factors which may affect growth in the GTHF.

These results have been used in regressions of growth (as a dependent variable) on a number of independent variables for -

(i) trees of all seventeen species measured;

(ii) tress of individual species measured;

(iii) trees of different girth classes of individual species;

(iv) tress of different economic classes;

(v) trees of different girth classes in the same economic class.

The independent variables include factors such as the presence of other trees and climbers, and crown density.

The regressions are based on REX Computer Programme modified by Philip West (Forestry Department, A.N.U.). The results of the regressions are based on increment records for a very short period; because of this the increment data cannot be regarded as representing the typical growth rates for the Bobiri Forest Reserve or for the GTHF; however, the growth data are a pointer to what is the likely biological behaviour of certain individual trees, species and economic classes within the GTHF.

The results of the regressions are discussed in four sub-sections:

(i) Growth trends of Class I species;

(ii) Growth trends of Class II species;

(iii) Growth trends of all economic species; and

(iv) Factors affecting growth.

It should be noted that the data in Table 12 cover a period of 2 years and that they were collected on potential as well as mature timber species, and that the results should reflect the behaviour of economic species through different girth classes.

TABLE 12 Summary of Growth in Basal Area in a 2-Year Period

Species		Growth in Basal Area in H.cm^2/Tree for the 2-Year Period						
		1in–1ft Girth	1–2ft	2–3	3–5	5–7	7–9	1 in–5ft+
	Economic Class	2.54–30.48 cm	30.48–60.96 cm	60.96–91.44 cm	91.44–152.40 cm	152.40–213.36 cm	213.36–274.32 cm	2.54–152.40+ cm
Chlorophora excelsa	Ia							2.14 0.89
Entandrophragma angolense	Ia	7.29 ± 1.00	13.29 ± 3.85	17.29 ± 2.79	46.38 ± 11.87			19.48 ± 2.78
Entandrophragma cylindricum	Ia	7.29 ± 2.00	7.29 ± 3.05	39.41 ± 9.86	49.02 ± 19.49	97.72 ± 17.48		48.50 ± 8.13
Entandrophragma utile	Ia	7.93 ± 2.14						21.48 ± 7.13
Khaya anthotheca	Ia	5.42 ± 1.20	18.25 ± 4.64	47.47 ± 9.79	62.63 ± 13.23	86.24 ± 33.90	231.62 ± 138.74	51.15 ± 14.22
Mimusops djave	Ia							70.89 ± 40.28
All above spp. together	All Ia	6.71 ± 0.67	14.84 ± 2.62	28.70 ± 3.74	49.21 ± 7.22	103.26 ± 25.28		34.83 ± 4.96
Triplochiton scleroxylon	Ib	10.13 ± 2.53	53.28 ± 9.74	66.50 ± 11.03	101.27 ± 9.22	126.29 ± 20.83	103.46 ± 34.34	85.40 ± 6.53
Triplochiton + other Class Ib spp.	All Ib	10.13 ± 2.53 (All trip)	46.44 ± 8.90	57.08 ± 10.32	97.40 ± 9.11	118.81 ± 15.61		81.01 ± 6.32
Entandrophragma candollei	IIa	4.13 ± 1.09	7.10 ± 2.46	86.30 ± 84.43				31.80 ± 23.86
Guarea cedrata	IIa	5.03 +0.43	13.35 + 3.33	29.35 + 4.88		30.70 +11.77		15.54 ± 1.78

TABLE 12 (Cont'd)

		Growth in Basal Area in H.m^2/Tree for the 2-Year Period						
		1 in–1 ft Girth	1–2 ft	2–3	3–5	5–7	7–9	1 in – 5 ft +
	Economic Class	2.54–30.48 cm	30.48–60.96 cm	60.96–91.44 cm	91.44–152.40 cm	152.40–213.36 cm	213.36–274.32 cm	2.54–152.40+ cm
Piptadeniastrum africanum	IIa	14.58 ± 4.60	10.51 ± 2.61	42.44 ± 10.32		125.90 ± 39.80		68.31 ± 10.84
All Class IIa species together	All IIa	5.48 ± 0.52	11.48 ± 2.01	41.60 ± 14.51	75.24 ± 15.51	78.30 ± 23.16		28.51 ± 4.05
Antiaris africana	IIb	4.52 ± 2.35	9.48 ± 5.69	12.38 ± 7.16	11.29 ± 3.52	19.54 ± 12.22	39.02 ± 16.57	16.64 ± 4.33
Nesogordonia papaverifera	IIb	4.58 ± .38	19.16 ± 5.88	43.80 ± 6.51	47.47 ± 7.42	46.50 ± 15.93		28.19 ± 3.19
Turreanthus africanus	IIb	9.16 ± 1.34	20.12 ± 3.22	36.38 ± 9.68	74.76 ± 8.21			51.08 ± 5.10
Mansonia altissima	IIb							10.70 ± 5.90
All Class IIb	All IIb	6.97 ± 0.69	17.80 ± 3.25	34.83 ± 4.59	45.30 ± [illegible]	82.11 ± 10.64		35.34 ± 2.77
All Economic Species (898 trees)	I + II							40.38 ± 2.25

Indicates that few specimens of higher girth classes were included

(Source: W.P. Branch, Ghana)

Two different girth classes have been shown, that is, 1ft girth classes for girths up to 3ft girth, and 2ft girth classes for all girths above 3ft. The latter became necessary in order to overcome any numerical deficiencies that use of 1ft girth classes for larger size trees would have encountered.

Any mention of growth in this context refers to growth in basal area per tree measured in sq. cms.

Growth Trends of Class I Species

Among the class Ia species *Entandrophragma cylindricum*, *Khaya anthotheca* and *Mimusops djave* showed the best growth of the trees recorded. *Triplochiton scleroxylon* (Class Ib) is distinctly the fastest growing species among the seventeen species recorded for all classes (Table 12).

Triplochiton scleroxylon has the highest stocking density among all the economic species. It is therefore not by accident that growth of class Ib species is very much related to that of *Triplochiton scleroxylon* (compare growth rates of *T. scleroxylon* and Class Ib in Table 12).

There was inadequate information on growth of 7-9ft girth class trees for all the economic class Ia species, but growth in the 5-7ft girth class tends to indicate that a 30 year time of passage may be reasonable between the 5-7ft and the 7-9ft girth classes. The greater difference in basal area between the 7-9ft and 9-11ft girth classes may mean that movement between these classes will not be achieved in 30 years. This is important because for class Ia species, trees cannot be exploited until they reach the 9-11ft girth class.

Even for the faster growing class Ib the average annual growth of 59cm^2 between 5-7ft and 7-9ft girth classes would take 28 years compared with the 22.5 years for a tree in the 5-7ft girth class to reach a MEG of 7-9ft.

Growth Trends in Class II Species

The species in this class as a whole are slower in growth than class I species. The average annual growth in basal area in the 5-7ft girth class is 39.15cm^2 for class IIa, and 40cm^2 for class IIb. These early results tend to indicate that the TOP for economic Class IIa should have been 42 years and not 22.5 years, and that of class IIb should have been 40 years instead of 30 years.

Trends in Growth of All Economic Species in General

There are wide variations in growth of individual trees, different species, girth classes, economic classes, etc., and some of these variations have been illustrated (Table 12). Times of passages are therefore at best very rough estimates of rates of growth. However, they are of important practical significance in the management of the GTHF.

For trees up to 1ft girth, most species are slow growing except for *Triplochiton scleroxylon*, *Piptadeniastrum africanum* and *Turreanthus africanus* which are relatively fast growing. Growth rates then accelerate in the 1ft-2ft girth class within which *Entandrophragma angolense*, *E. candollei*, *Guarea cedrata*, *Antiaris africana* and *Turreanthus africanus* double their previous growth rates, while *Khaya anthotheca*, *Triplochiton scleroxylon*, *Nesogordonia papaverifera* more than triple their previous growth rates. *Entandrophragma cylindricum* maintains the slow growth into the 1-2ft girth class, while *Piptadeniastrum africanum* slows down its intial faster growth.

Within the 2-3ft girth class Khaya anthotheca, Guarea cedrata, Nesogordonia papaverifera more than double their growth rates achieved in the 1-2ft girth class, while Entandrophragma cylindricum and Piptadeniastrum africanum more than quadruple their growth rates of the 1-2ft girth class. Beyond the 2-3ft girth class there is generally a slowing down of growth into the 3-5ft girth class. This is then followed by a further rapid increase in growth as the trees move into the 5-7ft girth class; exceptions to this include Antiaris africana and Guarea cedrata which continue to be relatively slow growing. There is inadequate information on increment within girth classes beyond the 5-7ft girth class, but the results for Khaya anthotheca and Triplochiton scleroxylon show that the former species continues to grow at a faster rate in the 7-9ft girth class, while the latter appears to attain its peak growth rate in the 5-7ft girth class.

Research on growth of economic species in the natural forest carried out in the Okomu Forest Reserve, Nigeria (Keay, 1961) indicated that Triplochiton scleroxylon and Piptadeniastrum africanum have the fastest growth rates and both attain their peak growth rates at around 6ft girth; and that for most species girth increment reaches its peak between 4ft and 9ft girths. Although conditions in Nigeria will not be the same as those of the GTHF, the pattern of growth appears to be similar. In general growth rates are different for all the species; these growth rates are low at the smallest girth classes and they increase at various rates into the 2-3ft girth class. Beyond this there is a slowing down of growth in basal area perhaps due to increased growth in height and crowns. Normal growth in basal area picks up again in the 5–7ft girth class, reaching its peak between 5ft and 9ft girths and then slowing down again. The results from Nigeria indicate that at 9ft girth the ages of Triplochiton scleroxylon, Piptadeniastrum africanum, Entandrophragma cylindricum, Khaya species, Guarea cedrata and Lophira alata may be estimated at 42, 71, 87, 88, 106, 137, 168 and 220 years respectively. The growth rates vary so much that a single satisfactory rotation cannot be fixed for all species.

The Nigerian experience based on annual measurements between 1934 and 1939, and periodic measurements between 1919 and 1934 in the Okomu Forest Reserve (Keay, 1961) reveal that the point of intersection of the maximum mean annual increment and the decreasing current annual increment for Entandrophragma angolense, E. cylindricum, Guarea cedrata, Khaya ivorensis, Lophira alata, Lovoa trichilioides may occur in girth classes 9–11ft, 13–15ft, 7–9ft, 9–11ft, 7–9ft, and 9–11ft respectively. This tends to suggest that the 9ft girth is a reasonable size for a rotation for those species. Again it was found that Entandrophragma cylindricum, Guarea cedrata and Triplochiton scleroxylon show substantial drops in utilizable volume due to unsoundness at girths of 30–31ft, 18–19ft and 21–22ft respectively. This tends to indicate that if the problem is not one of maximizing rotation of maximum volume growth then certain species may continue to grow at a decreasing rate of growth after the point of maximum mean annual increment has been reached, and that unsoundness resulting from physiological overmaturity does not necessarily occur soon after the growth rates start to decrease.

The Nigerian research results referred to may not be completely applicable to Ghana, but all indications are that the behaviour of the same species in Ghana may be very similar to that of Nigeria.

TABLE 13a Significant Results of the Multiple Regression Analyses of Growth in BA on Other Biological Factors

Species or Economic Class	Girth Class in Feet	(N-2) V	R^2 (%)	F	STD Reg. Coefficient (B) and its Significance (t) for each Variable (Xi)							
					X_3		X_4		X_5		X_6	
					B	t	B	t	B	t	B	t
Entandrophragma angolense	Under 1ft to 5ft+	99	36.48	** 13.77	.033	.143	-.236	.93	-17.48	** 6.36	.134	.91
All seven Class Ia Spp. Rec.	Under 1ft to 1ft.	80	14.21	* 3.21	-.058	.935	-.091	1.171	- 2.80	* 2.62	-.0071	.158
" "	Under 1ft to 5ft+	264	9.31	** 6.70	-.621	1.212	-.689	1.33	-15.60	** 2.96	.325	1.37
Triplochiton scleroxylon	Under 1ft to 1ft	8	84.30	* 6.69	-.158	1.44	-.483	* 2.683	-10.685	** 3.985	.189	1.734
" "	Under 1ft to 9ft+	122	21.44	** 8.12	-.454	.685	.358	.634	-30.41	** 4.61	-.349	1.126
Both Class Ib Spp. Rec.	Under 1ft to 5ft+	130	22.59	** 9.26	-.439	.70	.156	.290	-31.67	** 5.035	-.294	.976
Guarea cedrata	Under 1ft 5ft+	141	25.15	** 11.60	-.272	1.789	-.000 032	.000 15	-9.385	** 4.77	.056	.554
Piptadeniastrum africanum	5ft +	6	98.11	** 38.92	-9.33	** 5.686	8.093	* 3.072	-39.14	.658	1.807	1.363
" "	Under 1ft to 5ft+	44	44.31	** 8.16	-.883	.856	.630	.534	-38.51	** 3.72	.275	.603

(Source: Regression Analyses by L.K. Danso)

TABLE 13b Significant Results of the Multiple Regression Analyses of Growth in BA on Other Biological Factors

Species or Economic Class	Girth Class in Feet	(N-2) V	R^2 (%)	F	STD Reg. Coefficient (B) and its Significance (t) for each Variable (Xi)							
					X_3		X_4		X_5		X_6	
					B	t	B	t	B	t	B	t
All Four Class IIa Spp. Rec.	Under 1ft to 1ft	87	15.27	** 3.75	-.043	.956	.151	1.94	-2.248	** 2.682	.0235	.646
" "	5ft+	14	72.89	** 7.39	-6.01	** 3.417	6.43	** 2.977	-4.311	.1692	2.046	2.05
" "	Under 1ft to 5ft+	218	18.67	** 12.34	-.629	1.705	.0249	.0529	-20.66	** 4.71	.253	1.713
Nesogordonia papaverifera	Under 1ft to 9ft+	92	23.02	** 6.65	.257	.844	.0634	.2079	-13.923	** 4.627	-.0901	.5548
Turreanthus africanus	Under 1ft to 5ft+	122	39.18	** 19.16	.556	1.349	.7964	1.781	-38.17	** 7.914	.1033	.389
Antiaris africana	Under 1ft to 1ft	6	98.92	** 80.50	.822	** 15.025	-.788	** 8.753	-1.253	* 2.73	-.4019	* 9.677
All Four Class IIb Spp. Rec.	3ft to 5ft	66	20.19	** 3.98	1.416	** 2.870	-.3332	.6537	-5.743	.808	-.9494	** 3.314
" "	5ft to 0ft+	42	45.53	** 8.15	3.583	** 4.30	1.163	1.218	4.277	.4419	-.8176	1.576
" "	Under 1ft to 9ft+	278	16.71	** 13.79	.9699	** 3.829	.208	.759	-18.99	** 7.166	-.2257	1.507
All 17 Economic Spp. Rec.	Under 1ft to 5ft+	896	14.18	** 36.89	-.124	.5813	-.0776	.341	-22.016	** 9.759	.0147	.1318

(Source: Regression Analyses by L.K. Danso)

Factors Affecting Growth

In this sub-section an attempt has been made to examine the relationships between a number of stand factors and growth. This has been done by measuring a series of stand parameters and relating these through regression analyses to growth of trees by species, sizes and economic classes.

The stand parameters include:

(X_3) the number of neighbouring trees obstructing growth of the economic species;

(X_4) the number of neighbouring climbers obstructing growth of the economic species;

(X_5) Canopy density expressed as a percentage of the total shade cast on the forest;

(X_6) the number of trees of reasonable girth (girths in inches exceeding their distances in feet from the economic species) within a radius of 33ft (10m) and capable of exerting an adverse influence on growth (Y) of the seventeen different economic species recorded.

Other factors such as soil and climatic effects on growth were not measured and therefore not included in the regressions. Certainly because of this the parameters listed generally accounted for less than 50% of the variations in growth, as expressed by the multiple coefficient of variation, R^2.

The results of the regressions reveal some of the difficulties that can arise in dealing with the complex community of the GTHF. Some eighty regressions of Y on the independent variables were done but only 19 of these (Table 13) gave highly significant results which affected

(i) each of the following economic species taking all girth classes together: Entandrophragma angolense, Triplochiton scleroxylon, Guarea cedrata, Piptadeniastrum africanum, Nesogordonia papaverifera, Turreanthus africanus;

(ii) each of the economic classes Ia, Ib, IIa and IIb taking all girth classes together;

(iii) all trees irrespective of size, economic class or species; and

(iv) Antiaris africana in the <1-1ft girth class.

The highly significant results imply that there is a real relationship between growth in basal area and at least some of the independent variables for seven out of seventeen different species recorded. The relationship between growth in basal area and the independent variables for each of the remaining ten species must therefore be due to chance.

Standard regression coefficients for each of the parameters are listed (Table 13) to show which of the independent variables contributed most in explaining the variations in growth. In general crown density (X_5), and to a lesser extent the number of neighbouring trees (X_3) appear to be the most important variables.

In few cases, however, the number of climbers (X_4), and the number of trees within a radius of 33ft (X_6), appear to exert a considerable influence.

The significance of the regression coefficients found from t-test, where t = regression coefficient/standard error of the regression coefficient, confirms that X_5, and to a lesser extent X_3, exert generally strong negative and positive influences respectively on growth of the species affected.

In many instances the influences of all the independent variables except those of X_5 are due to chance; and for those instances a linear relationship could exist between growth (Y) and X_5 if the other variables were dropped.

The general inferences listed below can be drawn from the results of the regressions:

(i) Forest stand factors other than trees and climbers in the vicinity of the subject tree, and crown density may be more important in exerting influence on growth in basal area of potential economic trees of species such as *Chlorophora excelsa*, *Entandrophragma cylindricum*, *E. utile*, *E. candollei* and *Khaya anthotheca*. There were not enough data to draw similar inferences on *Mimusops djave*, *Lovoa trichilioides*, *Terminalia ivorensis* and *Mansonia altissima* which were among the ten species not significantly affected by the regressions.

(ii) The inherent characteristics of certain species are such that some amount of isolation, however small, may be enough to induce growth through the lower girth classes.

(iii) Canopy density appears to be a critical factor in the growth of such fast growing and shade intolerant species as *Triplochiton scleroxylon*, *Piptadeniastrum africanum*, *Turreanthus africanus*, *Nesogordonia papaverifera*, as well as slow growing trees such as *Entandrophragma angolense*, and *Guarea cedrata*.

(iv) *Triplochiton scleroxylon* appears to be sensitive to the effects of climbers in its early stages of growth. This may not be surprising as this species forms branches covered by dense foliage at a very early stage, under open conditions which also encourage the growth of climbers. Such climbers may cover the young trees and reduce the available light to the foliage.

(v) Piptadeniastrum africanum appears intolerant to competition from neighbouring trees when it reaches the medium girth class of 5-7ft; however, the effect of canopy density on it at this stage is insignificant. The source of the competition must therefore be the roots of the neighbouring trees. This species is widely distributed, especially in damp localities (Irvine, 1961); in the medium girth class when it attains rapid girth increments it may require sufficient nutrients in solution, and root competition from neighbouring trees can have a very important influence on the rate of growth at this stage.

(vi) In its early stages of growth (that is, in the <1-1ft girth class) Antiaris africana thrives well in the presence of other species provided it obtains sufficient light, but it is sensitive to the effects of climbers. The number of neighbouring trees and the number of climbers have highly significant positive and negative influences respectively on it while canopy density has a significant negative effect on it at the early stages of growth. This species regenerates best in more open forests of the ACA where the lower storey may be sufficiently dense to act as a camouflage against browsing animals and perhaps insect attack, and at the same time enable it to obtain sufficient overhead light. However, such areas may encourage the growth of climbers which are likely to choke the young tree.

(vii) Silvicultural management of the GTHF trees, either in natural forests or in man-made forests should pay sufficient attention to the characteristics of the various species with respect to light requirements and competitive ability in different girth classes.

TABLE 14 Morphological features in the form of Girth and Height Measurements.

GIRTHS IN cms.					HEIGHTS IN METERS				VOLUMES IN cu.m.				
Girth Around Buttress at 1.30m (X_1)	Girth Above Buttress (X_2)	Girth Below Crown (X_3)	Average Girth (X_4)	Mid-Girth (X_5)	Stump Height (X_6)	Bole Height Between X2 and X3 (X_7)	Crown Height (X_8)	Total Height (X_9)	Utiliz-able Volume (Y_1)	Non Utiliz-able Volume	Total Volume (Y_2)	Number of Trees	R^2 for Regression on
KHAYA ANTHOTHECA													
721.77 ±46.94	416.66 ±15.21	278.89 ± 7.49	347.78 ±10.61	323.39 ± 7.86	3.13 ±0.13	19.40 ±0.94	26.24 ±0.85	48.77 ±0.56	12.85 ±0.82	3.15	16.00 ±0.89	41	Y1=78.44 Y2=95.72
MIMUSOPS DJAVE													
591.01 ±26.57	470.92 ±20.30	308.46 ±12.59	390.14 ±15.18	345.03 ±12.74	2.66 ±0.12	26.30 ±0.51	19.92 ±0.66	48.89 ±0.80	21.95 ±1.70	3.88	25.83 ±0.69	28	Y1=62.53 Y2=98.96
ENTANDROPHRAGMA UTILE													
649.22 ±29.56	494.39 ±16.92	353.26 ±12.59	424.28 ±14.33	372.77 ±12.34	2.91 ±0.11	23.09 ±0.51	24.61 ±0.65	50.67 ±0.72	17.69 ±1.12	8,79	26.48 ±1.72	71	Y1=72.88 Y2=98.08
ENTANDROPHRAGMA ANGOLENSE													
619.66 ±26.55	383.13 ±11.31	254.20 ± 7.98	318.82 ± 9.20	298.09 ± 8.78	3.01 ±0.10	25.37 ±0.64	22.18 ±0.71	50.56 ±0.64	14.97 ±0.91	3.61	18.58 ±1.22	46	Y1=88.37 Y2=96.75

(Source: W.P. Branch Records, Ghana)

Canopy openings occur naturally in the GTHF as a result of windfalls, disease, senescence, etc., and the assisted canopy openings of the TSS and of the cyclical fellings (sub-section 32) appear to be fundamentally right. The only problems with the application of these systems concern the type of canopy manipulation that satisfies the light requirements of the relatively shade tolerant but more valuable economic species and the shade intolerant but less valuable economic species.

(viii) The TOP currently in use appear to have been underestimated. A minimum TOP of about 35 years for all economic class I trees between 7-9ft and 9-11ft girth classes and 40 years for Class II trees between 5-7ft and 7-9ft girth classes would appear to be more appropriate.

2.4.5.6 Morphological Features of Some Selected Dominant (Emergent) Trees of Economic Importance

Morphological features of selected emergent trees of economic importance are presented in the form of girth, height and volumes derived from data obtained from measurements carefully made in felling areas in the GTHF (Table 14).

These fellings were geared to the export market in the form of sawlogs, and the trees felled were of optimum quality in terms of form and size. The data therefore give some indication of -

(i) the sizes of timber trees likely to be found in the GTHF;

(ii) individual tree volumes; and

(iii) waste in logging.

The plank buttresses may cover a perimeter of over 6m. although they may be about 3m high. The average crown heights are about the same as the average bole heights, both being around 23m. Crown diameters were not recorded but these may be up to 18m. for these emergent trees.

The taper from above the buttress to below the crown for Khaya ivorensis, Mimusops djave, Entandrophragma angolense, E. cylindricum, are about 7cm/m, 6cm/m, 5cm/m and 6cm/m respectively. Volumes vary from $16m^3$ to $26m^3$ and waste in logging represents 15-33% of the total volumes.

2.4.5.7 Fauna of the GTHF

As well as trees the GTHF are the homes of millions of insects, birds, reptiles and many species of mammals, all of which are linked at various trophic levels and help to maintain the diversity and stability of the forests.

Insects and mammals are of great economic importance to Ghana and some attention is paid to them below:

Insects of the GTHF

Insects in general assist in pollination of flowers, in the dissemination of fruits, aeration of the soil; insects and bacteria are the decomposers and they form a very important link in the biological cycle.

Termites are very common and they play an important role in the breakdown of leaf litter, dead trees, dead branches and twigs.

In addition to termites are the ambrosia beetles belonging to two families, the Platypodidae and the Scolytidae (shorter and roundish). The common species are Doliopygus sp.(Platipodidae) and Xyleborus sp.(Scolytidae).

TABLE 15 List of Some Common Species of Mammals in the GTHF

FAMILY	SCIENTIFIC NAME	COMMON NAME	HABITAT	FEEDING HABIT
Bovidae	Tragelaphus scriptus	Bush buck	Near streams in humid areas	Herbivore
Bovidae	Taurotragus euroceros	Bongo	Near streams in humid areas	Herbivore
Bovidae	Cephalophus maxwelli	Maxwell Duiker	Near spots where forest has been disturbed naturally	Herbivore
Bovidae	C. sylvicultur	Yellow backed Duiker	Near spots where forest has been disturbed naturally	Herbivore
Bovidae	Neotragus pygmaeus	Royal Antelope	Near spots where forest has been disturbed naturally	Herbivore
Bovidae	Syncerus caffer nanus	Bush Cow	Near streams	Herbivore
Suidae	Potamochoerus porcus	Bush Pig	Near streams	Omnivore
Elephantidae	Loxodonta cyclotis	Forest Elephant	Near streams	Herbivore
Felidae	Panthera pardus	Leopard	Widespread	Carnivore
Rodentia	Protoxerus stangeri	Great Forest Squirrel	Widespread	Herbivore
Manidae	Phataginus tricuspis	Common pangolin	Widespread	Feeds on Insects
Cercophitecidae	Colobus badius	Red Colobus	Widespread	Herbivore
Cercopithecidae	C. verus	Olive colobus	Widespread	Herbivore
Cercopithecidae	Ceropithecus	Mona Monkey	Widespread	Herbivore
Cercopithecidae	C. diana	Diana Monkey	Widespread	Herbivore
Pongidae	Pan troglodytes	Chimpanzee	Widespread	Herbivore

- (Source: Animals of W.A. by Cansdale)

The Ambrosia beetles attack first the branches and then the boles of felled trees as well as standing but unhealthy trees by making numerous pinholes in which they introduce the ambrosia fungus on which they feed. (Bletchly, 1961). The life cycle is complete in 3-6 weeks, and they continue to breed uninterupted throughout the year.

Annual timber losses in Ghana resulting from ambrosia beetle attack on timber may run into millions of dollars. Triplochiton scleroxylon is especially susceptible to attack. It is known that high moisture content, high temperature, and chemical attractants such as alcohol predispose trees to attack by the beetles.

Long horn and Powder Post beetles also attack timber but they do not cause as much damage as the Ambrosia beetles.

Mammals of the GTHF

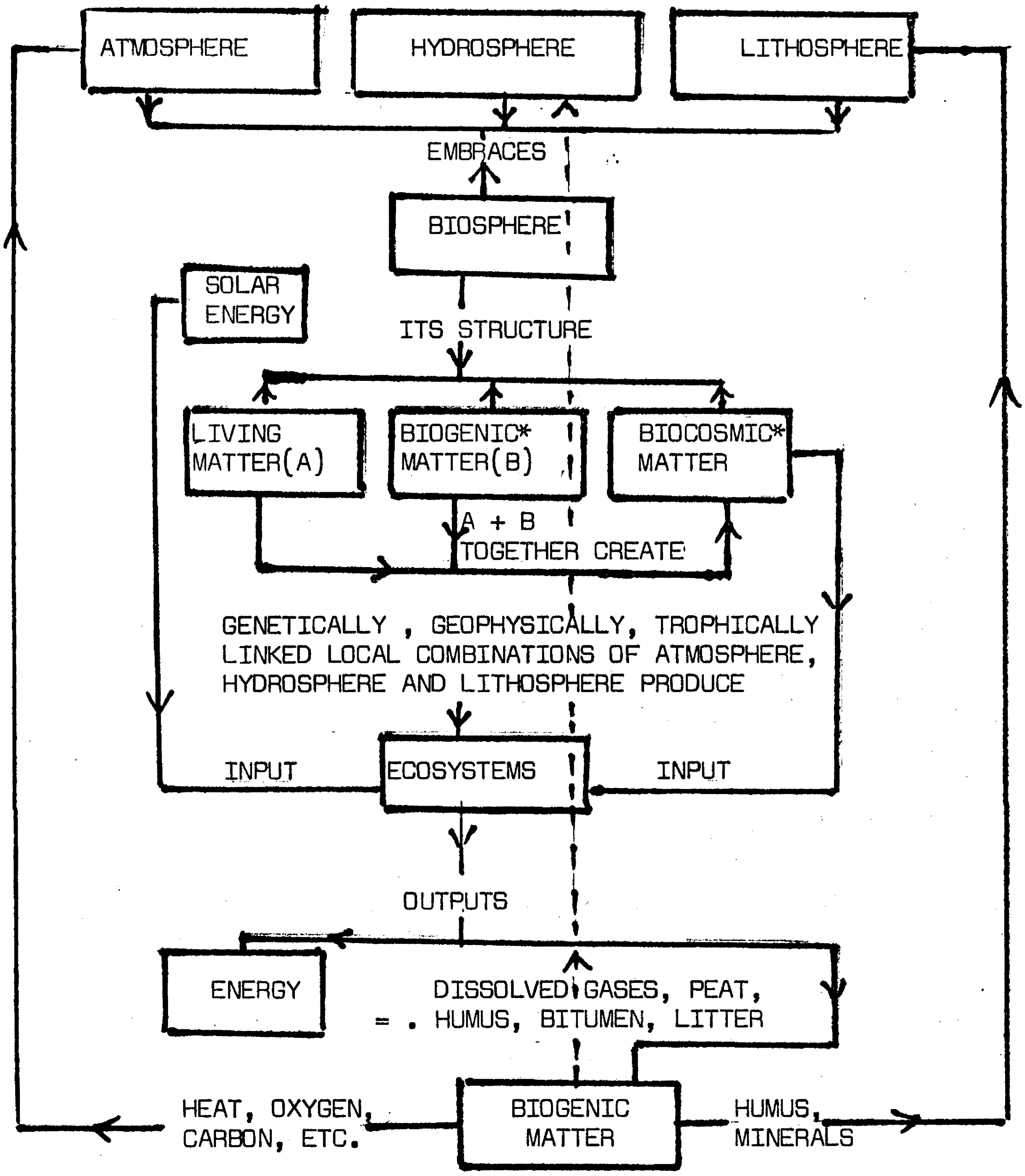
The mammals (Table 15) are the real foresters of the GTHF. They collect fruits, depulp them, pre-treat them for germination and disseminate them; they work the soil and at the same time manure and fertilize it; they consume enormous amounts of seeds and leaves and thus thin the forests and maintain the stocking at a reasonable density. The peaceful, humid and sheltered conditions of the GTHF are the ideal habitats of these mammals which have contributed immensely in the creation of those conditions.

In addition the mammals of the GTHF form a very important source of protein to millions of Ghanaians.

2.4.5.8. The GTHF as Part of the World Environment

This sub-section is intended to explain certain fundamental

TABLE 15A Exchange of Substances in the Biosphere



* BIOGENIC MATTER = Organic products created by Living matter, eg. coal, bitumen, combustible gases, peat, humus, litter.

* BIOCOSMIC MATTER = Mineral and other materials formed by living matter and biogenic matter combined, eg. gas composition in the lower layers of the atmosphere, sedimentary rocks, clay minerals, water.

(SOURCE: Derived from Contemporary Scientific Concepts of Biosphere by Kovda) ideas underlying conservation issues, and the need to maintain the bulk of the GTHF as a natural forest with as little disturbance as practicable.

The GTHF form part of ecosystems within the biosphere (Table 15A). Each ecosystem is thermodynamically open and it absorbs solar energy, mineral elements of rocks, atmosphere and water to produce energy and biogenic substances(Kovda, 1968). Natural ecosystems are relatively stable compared with those reversed, but even in stable ecosystems a gradual process of evolution takes place. New species appear and others disappear, with each species existing for some 30 million years.

The biomass, which is the total weight of orgamisms in the ecosystems, is made up of phytobiomass, zoobiomass and microbiomass. The biomass of the whole land surface of the world is estimated at about 3×10^{12} tons, and out of this the zoobiomass is estimated as being less than 1% of the phytobiomass which makes up most of the weight.

Humid tropical forests like the GTHF contain the largest amounts of phytobiomass which is of the order of 500 tons/hectare and over.

Each organism and its environment exchange elements in the form of solids, liquids and gases through trophic levels, disintegration of substances, etc. Living organisms (including man) contain about 65-70% of oxygen, 10% of hydrogen and 20-25% of other substances chiefly carbon, all of which are recycled among animals, trees and micro-organisms. The humid tropical forests like the GTHF have the largest daily productivity of about 10-20 grams (.35-.70 ounce) of carbon per square metre. Forests in general produce about 30% of the atmospheric oxygen. Like all ecosystems the GTHF possess a certain amount of plasticity and dynamism mainly because of their diversity.

They are also subject to periodic natural oscillations to which all organisms within them are adapted. However, if changes in the environment are more extreme than the natural oscillations then the plasticity breaks down and deterioration sets in. Such extreme changes may be brought about by the cumulative effects of of the following:

(i) Road construction through previously undisturbed forest which is accompanied by removal of many trees and the predisposing of the forest soil to erosion.

(ii) Loosening and compaction of the forest soil at loading stations and along snig tracks by moving machines, sawlogs and human feet.

(iii) Flooding, turbidity and accelerated ageing of rivers and streams caused by eroded soils from roads, loading stations and snig tracks.

(iv) Fouling of the suitable environment for spawning fish resulting from variations in depth, velocity, temperature, suitable chemical content of water which can be caused by the accumulation of soil, leaves and branches of felled trees.

(v) Disturbance of wildlife by the noise caused by humans, falling trees, machines, as well as by pollution of the environment by poisonous fumes.

(vi) Fouling of the general forest environment by fossil fuels, empty cans, worn-out parts of machinery, barks of trees, waste paper and plastics.

(vii) Extensive clearings of climatic climax forests and fires.

Such cumulative effects can lead to the disappearance of certain species and animals long before their normal period of existence comes to an end. In addition they can destroy future recreational values such as waterfalls and rapids, virgin forest, and geomorphic features that attract all sorts of people who may go out into the GTHF to improve their health, recapture pioneer spirit, acquire knowledge, lead simple lives, relieve tensions, attain new perspectives, breathe fresh air, get physically tired or satisfy their emotions (Hendee, 1969).

2.5 ECONOMIC CONSIDERATIONS

In previous sections an attempt has been made to reveal the nature and the operations of ecological and biological factors that control the existence of the GTHF.

This section will consider the uses to which the forests are being put for the benefit of Ghanaians in particular, and the world in general.

The section has rightly been divided to deal with the following:

(i) The objectives of Management and the Alternative uses of the GTHF.

(ii) Forest Industries and Markets and Market situation.

(iii) Supply and demand and forecasts of future supply and demand.

2.5.1 Objectives of Forest Management

The above is as outlined in the quotation below: "The creation of permanent forest resources by reservation, either by central government or by local authority of suitably situated areas of forest or land desirable and suitable for afforestation of a total extent sufficient to supply the benefits necessary for the welfare of the people - indirect benefits in the form of preservation of water supplies, maintenance of climatic conditions favourable to the growth of the principal agricultural crops and minimization of erosion, and direct benefits in the form of sustained adequate supply of forest produce to meet actual and potential local requirements and the demands of the export trade."

The main objectives as outlined above are rightly the welfare of the people of Ghana expressed in terms of social and economic benefits. The ultimate social benefits are good health and better expectation of life resulting from the supply of good drinking water, pure air and good food; and the economic benefits are increasing affulence resulting from the sale of timber and agricultural products such as cocoa to countries outside Ghana and to Ghana itself. However, there are opportunity costs, of the land resource devoted to forestry , in terms of other uses. These are dealt with in the next section.

2.5.2 Alternative Uses of the GTHF

Soil conditions and legal position already dealt with show that some of the best agriculture soils are under permanent forest and that there is an increasing pressure for the release of forest land for farming. The fact that over 24,450 sq. miles (63,196 sq. Km) or over 77% of the GTHF are under permanent cocoa farms and bush fallow underscores the importance of competing uses, of the forest land, which have been listed below:

(i) Continuation of management as a natural tropical high forest.

(ii) Removal of Natural forest and establishment of forest plantations.

(iii) Removal of natural forest and its conversion to a mixture of cocoa farms and forest plantations.

(iv) Removal of the natural forest and its conversion to cocoa and food crop farms.

(v) Removal of the natural forest and its conversion into oil palm and rubber plantations.

(vi) Removal of the natural forest and establishment of other industries such as mining, textile, etc, industries.

Alternative (ii) is currently being practised, alongside the management of the natural tropical high forests (Alternative 1) in those areas where the stocking of economic species is so poor as to make them uneconomic to retain as natural forests. This complementary alternative will be broadly treated under management systems (Section 3).

Accessibility, proximity to factories and markets, and relative cheapness of conversion of existing fallow areas to agricultural plantations such as oil palm and rubber, preclude the use of permanent forest reserves for these crops. An exception is the Neung Forest reserve (64.74 sq. miles or 167.68 sq. Km) which is located close to a rubber factory and also has an old but small rubber plantation within it. However, this reserve has some diamond deposits which provide private enterpreuhership and alternative employment to the rural population in the area. Moreover, control exercised by the Forestry department has resulted in reduction of water turbidity problems caused by diamond prospecting, to a far greater extent than that of unreserved areas nearby.

Mining for gold and manganese are important but experience from Tarkwa and Obuasi have shown that natural forests and mining can co-exist to their mutual advantage. Accessibility and proximity rule out the establishment of other industries and townships.

TABLE 16 Contribution of Cocoa to the Ghanaian Economy

YEAR	COCOA EXPORTS (RAW BEANS)		EXPORT DUTY ON COCOA		PERCENTAGE DISTRIBUTION BY VALUE OF EXPORTS	
	QUANTITY IN 1000 METRIC TONS	VALUE IN MILLION CEDIS	VALUE IN MILLION CEDIS	PERCENTAGE OF GHANA GOV'T REVENUE	COCOA INCLUDING COCOA PASTE AND BUTTER	TIMBER LOGS AND SAWN
1962	429.77	134.13	25.0	16.4	63.3	11.0
1963	410.46	135.54	29.0	17.2	66.7	12.1
1964	388.11	136.23	29.7	11.7	64.8	13.0
1965	501.90	136.48	19.7	7.0	66.6	11.0
1966	397.26	103.06	15.3	6.6	62.3	11.3
1967	333.25	130.67	34.7	13.7	64.9	9.3
1968	334.26	185.60	69.7	23.4	63.4	8.5
1969	307.85	218.56	98.1	29.5	62.9	10.0

(Source: Ghana Govt. Economic Survey 1968)

Cocoa farming (in alternatives (iii) and (iv)) is then the most important potential user of the forest soil resource to compete with the management of the GTHF as natural forests (alternative i).

The average annual outturn of raw cocoa beans (Table 16) together with cocoa paste and cocoa butter manufactured in Ghana is about 420,000 long tons (426,720 metric tons). The total annual production of cocoa paste and butter is about 40,000 long tons (40,640 metric tons). The value of exports of cocoa beans, cocoa paste and butter annually is about ₵164 million and approximately 10% of this revenue is derived from the manufacture of cocoa paste and butter. The total value of the annual exports of cocoa beans, paste and butter represents over 60% of the total export earnings while the total value of the annual export earnings from sawlogs, and lumber represents approximately 11% of the total annual export earnings for Ghana (Table 16).

Export duty on cocoa has accounted for about 7-29% of the annual revenue for the central government.

About half the cocoa farms in full bearing stage are sited on marginal cocoa soils (Table 6). Moreover, on similar soils as well as on better soils, the cocoa farms in full bearing stage vary in age and productivity. Therefore it is reasonable to estimate the annual outturn of cocoa beans per hectare at 875lbs. (398kg.), instead of the higher figures in table 6. On this basis the effective area of cocoa farms in full bearing stage is about 4200 sq. mls. (1,075,200 ha.).

The total amount of work on cleaning, harvesting, bagging, etc, in one hectare of mature cocoa farm is about 64.5 man-days per annum (Urquhart, 1955). Since farmers spend about one-third of their time on mature cocoa farms, the estimated number of people engaged directly on cocoa production in villages (excluding all those people who spend their time on young cocoa farms under 8 years old, and rehabilitation of old abandoned farms) is approximately 693,000. Since some of these people spend part of the remaining two-thirds of their time on young cocoa and foodcrop farms, they also account for a large percentage of crops used as stable diet in the high forest zone of Ghana.

In addition there are some 10,000 persons engaged in buying, transporting cocoa by road, rail and sea.

Cocoa production has a strong backward linkage in the form of manufacture of cutlasses locally in Ghana and abroad. It also has a very important forward linkage in the manufacture of jute bags which are the only containers for cocoa beans. These bags are manufactured locally in Ghana. Cocoa production also has a tremendous stimulating effect on dwelling construction which absorbs over 60% of the fixed annual capital formation in Ghana, and employs thousands of artisans and labourers. These factors concerning the contribution of cocoa to the Ghanaian economy leave no doubt that cocoa growing is clearly a better alternative than the maintenance of the GTHF under permanent forest management.

The short-term effect of complete replacement of forests by cocoa could be a doubling, and perhaps tripling of the volume and value production level shown in Table 16 during the next 10-15 years.

This could meet the ever-souring demands for cocoa products; but on the other hand it could, perhaps, create a slump in the marketing of cocoa if overproduction is, in fact, permitted.

A massive expansion in cocoa production might necessitate the importation of timber for building constructions in Ghana, and the laying off of many of the foresters, clerks and labourers engaged directly in forest management in Ghana (Table 31), and over 35,000 technicians and labourers engaged in logging, sawmilling, transportation of timber by road, rail and sea, not to mention the employees of the Ghana Timber Marketing Board (GTMB).

Despite the economic justification for the establishment of cocoa farms, there could be serious ecological consequences resulting from a massive clearing of the GTHF for cocoa production. The long term effect of such a decision could mean that the suitable climatic conditions maintained by the natural forests for the growth and development of healthy cocoa and other food-crops could be adversely affected. This would result in the gradual decline of cocoa as an important export crop of Ghana. The thought of famine with the disastrous consequences that go with it, is enough to dismiss total clearing of the GTHF for cocoa production as a valid alternative to the maintenance of some 20% of it under permanent forest management.

The alternative to pure cocoa plantations could be the establishment of mixtures of open-crowned economic species such as <u>Entandrophragma angolense</u>, <u>Terminalia ivorensis</u>, <u>Triplochiton scleroxylon</u>, etc, over a closed lower storey of cocoa trees. The result would be a two-storied high forest containing a plagioclimax, closed, one species layer of cocoa lying below an open forest of few climatic climax species. The multi-species, multi-sized, multi-structured natural forest communities in dynamic equilibrium with other biotic as well as climatic and soil factors of the habitat would be lost forever; and gone with them would be the vertical sieve they form, for at least 20 metres, against violent wind movements to maintain permanent moist soil conditions and humid atmosphere; instead they would be replaced by an unstable low canopy of about 5 metres high formed entirely by cocoa which also places heavy demands on soil fertility and creates no effective barrier to the movement of the north-east trade winds. It would be unwise to jeopardise the future of a stable cocoa industry and abundant food production because of a short-term benefit which on the basis of recent experience elsewhere in Africa could result in the covering of the skies of Ghana with permanent haze (instead of rain carrying clouds) by the harmattan winds. The protective role of the GTHF to food crops, cocoa crops, soil and water, ranks so high (in terms of social benefits) that not only should forests strategically located to serve the stated objectives be managed as natural forests, but also it should be made possible to establish forests in areas where soil denudation and water turbidity are on the increase, in both the GTHF and in the GSW.

TABLE 17 - Components of the Forest Industry

NO.	TIMBER INDUSTRY PROPER				COTTAGE INDUSTRY	
	PRODUCERS OF	BUYERS	CONTROL	USERS	PRODUCERS OF	USERS
1	Logs	Log Exporters and Saw-mills	Timber Inspection Branch of Forestry Department and GTMB	Mainly Western Europe & Ghanaians	Firewood	Ghanaian Public
2	Lumber	Lumber Exporters and Local Retailers		"	Charcoal	Ghanaian Public
3	Veneer and Plywood	Veneer + Plywood Exporters and Local Retailers	"	"	Chewing Stick	Ghanaian Public
4	Mine Timber	Gold Mines		Mines in Ghana	Mortar and Pestle	Ghanaian Public
5	Railway Sleepers	Ghana Govern-ment		Ghana Railways	Cane Basket	Ghanaian Public
6					Carvings	Ghanaian Public
7					Palmwine	Ghanaian Public
8					Quarried Stones	Ghanaian Public
9					Game Animals	Ghanaian Public
10					Herbal Medicine	Ghanaian Public
11					Others	

(SOURCE: From Personal Experience)

2.5.3 Forest Industries Connected with the Management of the GTHF

Those industries which concern the production of sawlogs, veneer and plywood, mine timber, railway sleepers, firewood, charcoal, etc. (Table 17) are discussed in the following sub-sections.

2.5.3.1 Sawlog Production

All areas carrying timber trees must first be acquired by Timber Producers (Concessionaires) as concessions before arrangements for logging can take place.

It is the responsibility of the concessionaire to

(i) search for the potential timber land which should not be covered by any Felling Agreement (also called Concession Agreements) at the time the land is found,

(ii) arrange for the preparation of Felling Agreement which should be signed by the Minister responsible for Lands on the advice of Forestry and Lands Departments,

(iii) register the Felling Agreement as a Legal Document, and

(iv) deposit two copies of the Felling Agreement with the CCF.

Logging should not normally begin until the CCF has authorised the allocation of specific annual coupes. In the case of Forest Reserves such authority is given only after the WP has been prepared and approved by the CCF. In the case of unreserved forests concession reports must first be approved by the CCF before the authority may be given; these concession reports must be prepared by the District Forest Officer. However, the number of Felling

Agreements covering potential timber lands in unreserved forests at any one time has been so great that it has not been practicable to prepere concession reports to enable the CCF to exercise control over fellings outside Forest Reserves.

The concessions may cover areas varying from 3sq. mls. (8sq. km) to 50sq. mls. (130 sq.km), or even more, and they may be held for a period of 3–25 years or more during which the concessionaire pays annual rents.

Logging operations involve the removal of about 5–10 trees per hectare in Forest Reserves. This may be equivalent to the removal of about 78–156m^3 per hectare. Outside Forest Reserves concessionaires fell all timber trees that can be converted into lumber, veneer and plywood.

When well organised logging is preceded by enumeration of merchantable trees and topographical surveys, road construction, preparation of loading stations and campsites. Felling and extraction are carried out in a ½sq.ml. (1.30sq.km.) block at a time, and there may be at least 1–1½ miles (1.6–2.4Km) of road per square mile depending on the nature of the terrain, stocking density, and accessibility. Each loading station may measure 200ft. x 300ft. (61 x 92m.), and it is usually located in areas with high concentrations of merchantable trees. Snig tracks (hauling tracks) radiate from the loading stations to the felling areas. Fellings are done with power saws by a team of two men felling about 15 trees on an 8 hour day – this may amount to at least 80 tons of timber per day.

The sawlogs are hauled with winches and logging arches to loading stations for debarking with axes, and then loaded on to

TABLE 18 – Production, Exports and Consumption (Locally in Ghana) for the Period 1966–1972 in 1000 M^3

		1966	1967	1968	1969	1970	1971	1972
Population (Millions)		7.96	8.14	8.35	8.57	8.78	9.000	9.23
GDP per Capita at 1960 Prices		140.0	140.00	138.0	140.0	142.0	147.0	147.0
Consumption of Sawn Timber/capita(M^3)		.024	.018	.0144	.017	.0142	.0157	.011
Consumption of Plywood + veneer per Capita (M^3)		. 003	.0012	.0008	.0004	.0011	.0015	.0023
Total Log Production		1388	1342	1388	1611	1563	1624	1878
Production from Forest Reserves		552	527	439	657	771	827	1149
% Contribution by Forest Reserves		39.77	39.27	31.63	40.78	49.33	50.92	61.18
Production	Sawn Timber	397.28	336.45	335.31	365.03	365.30	327.17	347.68
	Veneer and Plywood	21.56	27.53	27.61	25.80	31.74	39.90	46.91
	Total	418.84	363.98	362.92	390.83	397.04	367.07	394.59
Exports	Sawlogs	476.00	505.00	569.00	696.00	600.00	706.00	951.00
	Sawn Timber	204.87	189.30	215.05	218.73	240.52	185.62	250.28
	Veneer + Plywood	18.96	18.11	20.77	22.22	22.10	26.77	25.70
Local Consumption	Sawlogs used in Mills	912.00	837.00	819.00	915.00	963.00	918.00	927.00
	Sawn Timber Consumption	192.41	147.15	120.26	146.30	124.78	141.55	97.40
	Veneer + Plywood Consumption	2.60	9.42	6.84	3.58	9.64	13.13	21.21
% Waste in Log Conversion		54.07	56.51	55.69	57.29	58.77	60.01	57.43

(SOURCE: F. Dept. Ghana, Annual reports, Central Bureau of Stats. Ghana) trucks with the aid of the high lead system. Sawlogs finally find their way to sawmills, veneer and plywood mills or to countries overseas. (Table 18).

2.5.3.2 Lumber Production

Most timber firms commence business as sawlog producers and those which become well established may expand operations into sawmilling. Lumber fetches a higher price, and its strong backward linkage helps to introduce producers to the business complexities of the timber world.

Sawmills range from those using only small mobile circular saws or water-cooled but fixed circular saws, through numerous small mills with band saws and gang saws (usually bought secondhand from Europe), to large and well organised mills such as those of Glikstan (WA) Ltd. and African Timber and Plywood Ltd. The large mills have log ponds, log yards, band saws, gang saws, edgers, circular saws, grading section, kilns, sales representatives in various countries, housing for employees, large timber concessions, etc. The daily consumption of the larger mills may be as high as 10,000cu.ft. (283M^3) of sawlogs.

The best quality lumber, which may be graded as Firsts and Seconds (FAS), No. 1 Common, Selects, Prime Flooring Strips, Blocks and Scantlings, and Flitches, etc, are usually exported. Table 18 gives the quantities of lumber produced, exported and locally consumed in the period 1966-1972.

2.5.3.3 Veneer and Plywood Production

This is the most capital intensive sector of the industry, and it requires a considerable managerial expertise. The two large firms previously mentioned (sub-section 2.5.3.2) and a few others such as Naja David are involved in veneer and plywood production.

The mills are usually modern, with steaming pits for sawlogs of Entandrophragma cylindricum, E. angolense, E. candollei, Tarrietia utilis, Turreanthus africanus and Guarea cedrata. Their technology includes use of slicers or peelers, clippers, sorters, roller bearing driers, core pluggers, edgers, gluing machines, pressers, sanders, sizers, etc.

They employ well trained technicians and saw doctors. Annual production per mill varies from 14,500cu.ft. ($410.53M^3$) to 494,480cu.ft. ($14,000M^3$).

The best grades of plywood - marine, gold, silver or 3 - star, 2 - star and 1 - star grades, as well as those of veneer, go to the export market. Table 18 gives the total production and consumption of veneer and plywood for the period 1966-1972. Tables 22 and 23 give the list of major species used for veneer and plywood as well as lumber.

2.5.3.4 Mine Timber and Railway Sleepers

Mine timber for use in the Obuasi, Tarkwa, Bibiani, Prestea, and Konongo Gold Mines, and railway sleepers required by the Ghana Railways, form a small percentage of the timber produced. Both use species such as Cylicodiscus gabunensis, Strombosia glaucescens, Chlorophora excelsa, Piptadeniastrum africanum, Nauclea diderrichii, Lophira alata which have high density and strength, and respond to preservative treatment.

Mine timber and railway sleepers demand rigid specifications as to strength, sizes, toughness and durability, and only few reliable sawmills can produce them. High transport costs limit the distance for the supply of mine timber, and Obuasi Gold Mines have had to establish Teak and Eucalypt Plantations as a source of their mine timber supply. Railway sleepers have a better market and may become an important export timber in future; for example Egypt is interested in buying railway sleepers from Ghana.

2.5.3.5 Cottage Industries

A considerable number of persons in the rural population of some 7 million depends partly for subsistence on some cottage industry, particularly those sectors of the industry based on the existence of a natural tropical high forest.

Such industries supplement farm revenue, and they are particularly important during off-season periods for farming.

Some of these industries date back to ancient times but surprisingly have kept pace with modern developments and may be highly competitive with products of modern industrial technology. Many examples can be cited - The wig support, travelling and shopping bags, boxes, garbage baskets, babies cots, hotel easy chairs, etc, are made by skilled craftsmen in rural areas from climbing species of palmae such as Ancistrophyllum opacum, A. secundiflorum, Calamus deeratus. Baskets made from the oil palm tree (Elaeis guineensis and the raphia palm (Raphia hookeri) are indispensable containers to all types of farmers. Carved stools, kitchen utensils, combs, walking sticks, are common household items made from Alstonia boonei, Holarrhena wulfsbergii and many other species. Many Ghanaians will not take breakfast or retire for the night without first cleaning their teeth with chewing stick produced from Garcinia cola, Trichilia spp., etc. There would be a few homes in Ghana in which the mortar and pestle, used for food preparation, cannot be found. The mortar is usually carved from Nauclea diderrichii, and the pestle is made from Celtis and Morus spp.

Palm wine, which is a common filling, refreshing and relaxing drink of the general public, is produced from the oil palm tree and the raphia palm. Almost all species in the GTHF are involved in one way or the other in preparation of herbal medicines; many have powerful curative powers and are even used in some hospitals alongside modern extractives. The production of dyes and tanning, rubber, sponge, spices, oils, farm poles, honey, and the supply of materials for dwelling construction in villages as well as bushmeat, fish, snails and fruits, etc, depend on the permanent forest estate for a sustained supply of raw materials. Without these raw materials the self-sufficient rural dweller would be a burden to the Ghana government.

TABLE 19 - Ghanaian Sawlog and Lumber Supply to Ghana and other Countries in $1000M^3$

	GHANAIAN SAWLOGS							GHANAIAN LUMBER						
	PRODUCTION	SUPPLY TO WESTERN EUROPE		SUPPLY TO MILLS IN GHANA		SUPPLY TO OTHER COUNTRIES		PRODUCTION	SUPPLY TO WESTERN EUROPE		SUPPLY TO GHANA		SUPPLY TO OTHER COUNTRIES INCLUDING N. AMERICA	
	TOTAL	TOTAL	% OF PRODUCTION	TOTAL	% OF PRODUCTION	TOTAL	% OF PRODUCTION	TOTAL	TOTAL	% OF PRODUCTION	TOTAL	% OF PRODUCTION	TOTAL	% OF PRODUCTION
1966	1388	386.8	27.87	912	65.71	89.2	6.42	397.28	128.0	32.21	192.41	48.43	76.87	19.36
1967	1342	384.6	28.65	837	62.37	120.4	8.98	336.45	127.3	37.84	147.15	43.74	62.0	18.42
1968	1388	448.7	32.33	819	59.01	120.3	8.66	335.31	162.2	48.37	120.26	35.86	52.85	15.77
1969	1611	538.6	33.43	915	56.80	157.4	9.77	365.03	150.2	41.15	146.30	40.08	68.53	18.77
1970	1563	428.7	27.43	963	61.61	171.3	10.96	365.30	136.0	37.22	124.78	34.16	104.52	28.62
1971	1624	506.1	31.16	918	56.53	199.9	12.31	327.17	125.4	38.33	141.55	43.26	60.22	18.41
1972	1878	742.8	39.55	927	49.36	208.2	11.09	347.68	139.7	40.18	97.40	28.01	110.58	31.72
MEAN FOR 7 YEARS	1542	491	31.49	899	58.77	152	9.74	353	138	39.33	139	39.08	77	21.58

TABLE 20a Trade Between 7 European Countries and 8 Major Tropical Timber Producing Countries

	TRADE IN LOGS IN $1000M^3$								
Year / From	1966	1967	1968	1969	1970	1971	1972	1973	Total
Ghana	386.8	384.6	448.7	538.6	428.7	506.1	742.8	644.0	4080.3
Ivory Coast	1591.8	1797.4	2079.5	2530.8	2306.7	2419.4	2747.8	2936.7	18410.1
Nigeria	489.8	303.1	251.8	274.3	171.9	168.4	141.3	196.3	2005.9
Cameroon	230.6	207.2	240.0	253.1	370.7	411.1	292.8	388.5	2394
Gabon	1020.4	973.1	990.5	1090.2	1086.0	1103.4	1175.9	1218.7	8658.2
Zaire	94.10	84.1	75.9	103.8	-	-	-	-	357.9
Congo Brazzaville	369.4	343.1	399.1	407.3	368.0	331.7	292.2	230.4	2741.2
Total from W. Africa	4181.9	4092.6	4485.5	5198.1	4732	4949	5402.8	5614.6	38647.6
Malaysia	117.7	113.8	125.3	68.9	-	-	-	-	425.7
GRAND TOTAL	4299.6	4206.4	4610.8	5267.0	4732.0	4940.0	5402.8	5614.6	39073.3

(Source: FAO, Geneva: Annual Forest Products Market Review)

<u>TABLE 20b</u> Trade Between 7 European Countries and 8 Major Tropical Timber Producing Countries

From / Year	TRADE IN SAWN TIMBER IN 1000M^3								
	1966	1967	1968	1969	1970	1971	1972	1973	Total
Ghana	128	127.3	162.2	150.8	136.0	125.4	139.7	164.9	1134.3
Ivory Coast	122.1	137.4	165.1	148.0	151.1	144.8	140.5	176.0	1185.0
Nigeria	49.9	43.8	50.9	45.0	39.20	25.60	25.1	30.6	310.1
Cameroon	-	-	-	-	18.8	20.2	16.3	23.8	79.1
Gabon	-	-	-	-	-	-	-	-	-
Zaire	35.7	27.3	32.5	31.0	30.2	30.6	30.3	38.0	255.6
Congo Brazzaville	-	-	-	-	-	-	-	-	-
Total from W. Africa	335.7	335.8	410.7	374.8	375.3	346.6	351.9	433.3	2964.1
Malaysia	371.1	387.7	535.0	639.7	690.4	657.5	866.7	1310.7	5458.8
GRAND TOTAL	706.8	723.5	945.7	1014.5	1065.7	1004.1	1218.6	1744.0	8422.9

(Source: FAO, Geneva: Annual Forest Products Market Review)

2.5.4 Markets and Market Structure

2.5.4.1 Markets

Ghana timber is sold in the form of sawlogs, lumber, veneer and plywood to two important markets, namely, the local Ghanaian Market and the Export Market. Data for the period 1966–1972 (Table 19) indicate that approximately 59% of the annual production of sawlogs go to mills in Ghana, and about 39% of the lumber produced locally in Ghana is sold to Ghanaians. The quantity of veneer and plywood sold to Ghanaians is generally small compared with the quantities of sawlogs and lumber also sold locally; but while the local market for sawlogs has remained fairly stable and that of lumber has shown a slight decline during the seven year period (Table 19), the market for veneer and plywood has increased from 12% of the total production of veneer and plywood in 1966 to 45% in 1972 (Table 18).

The Export Market absorbs reasonably large quantities of Ghana timber. The data for 1966–1972 (Table 19) indicate that about 40% of the total production of sawlogs and about 60% of the total production of lumber are exported.

The most important export market is Western Europe which buys about 76% of the total sawlog exports and 65% of the total lumber exports. The Western European market is important not only to Ghana, but also to the other West African countries, and indeed to other countries such as Malaysia that export tropical hardwoods (Table 20). In fact Ghana's share of the total annual West African sawlog export to Western Europe is about 11%, and that of

TABLE 21(a) - Export of Sawlogs from West Africa to Western Europe (1967-1968) in 1000 M^2

TO / FROM	BELGIUM LUXEMBERG		DENMARK		FRANCE		ITALY		NETHERLANDS		U.K.		WESTERN GERMANY		TOTAL	
	1967	1968	1967	1968	1967	1968	1967	1968	1967	1968	1967	1968	1967	1968	1967	1968
Ivory Coast	91.6	106.1	45.5	44.2	480.6	538.5	541.7	590.8	58.9	71.1	74.0	104.9	505.1	623.1	1797.4	2079.4
Gabon	14.3	15.0	7.2	14.1	694.8	696.5	11.8	18.2	31.6	32.9	9.3	4.9	204.1	209.2	973.1	990.5
Ghana	2.5	2.2	4.5	8.0	34.6	31.6	112.1	124.4	8.6	14.9	55.9	66.2	166.4	201.4	384.6	448.8
Congo Brazzaville	9.7	10.7	8.2	3.9	57.2	45.3	22.6	10.9	34.4	55.6	9.0	10.6	202.0	262.1	343.1	399.1
Nigeria	8.6	4.1	12.2	13.0	2.9	6.1	73.6	60.9	6.6	7.9	80.1	91.9	119.1	68.0	303.1	251.7
Cameroons	23.8	23.8	3.9	4.2	26.2	24.1	29.5	31.9	63.2	89.4	21.5	23.6	39.1	43.0	207.2	240.0
Zaire	14.1	11.4	1.8	0.8	1.7	4.6	23.4	29.0	0.4	1.7	1.8	1.1	41.4	27.3	84.6	75.9
Total	164.6	173.3	83.3	88.2	1298	1346.7	814.7	866.1	203.7	273.5	251.6	303.2	1277.2	1434.1	4093.1	4485.4

(SOURCE: Annual Forest Products Market Review)

TABLE 21(b) - Export of Sawn Timber from West Africa to Western Europe (1967-1968) in 1000 M^2

TO / FROM	BELGIUM LUXEMBERG 1967	BELGIUM LUXEMBERG 1968	DENMARK 1967	DENMARK 1968	FRANCE 1967	FRANCE 1968	ITALY 1967	ITALY 1968	NETHERLANDS 1967	NETHERLANDS 1968	U.K. 1967	U.K. 1968	WESTERN GERMANY 1967	WESTERN GERMANY 1968	TOTAL 1967	TOTAL 1968
Ivory Coast	2.5	4.1	1.9	2.1	52.9	66.5	4.5	5.5	8.2	11.6	61.2	67.5	6.2	7.9	137.4	165.4
Ghana	0.7	0.8	1.2	0.6	0.8	0.6	7.9	9.5	6.2	8.6	106.7	137.4	3.8	4.3	127.3	162.3
Nigeria	0.3	0.6	0.2	0.2	0.1	0.1	0.4	0.3	2.2	2.0	39.6	46.8	1.0	0.9	43.8	50.9
Zaire	5.0	4.3	0.1	-	0.1	0.1	0.6	0.6	2.6	3.2	6.8	7.8	12.2	16.5	27.4	32.5
Total	8.5	9.8	3.4	2.9	53.9	67.3	13.4	15.9	19.2	25.4	214.3	259.5	23.2	29.6	305.8	411.1

(SOURCE: Annual Forest Products Market Review) lumber is approximately 38%.

Seven West European countries are the main buyers of Ghana and West African timber. Data for 1967-1968 (Table 21) giving the break-down of West African hardwood exports to Western Europe indicate that West Germany, France and Italy absorb large quantities of West African hardwoods in the form of sawlogs, and that the United Kingdom buys about half the total annual production of lumber from the four main West African countries that export lumber.

The most important markets for Ghana sawlogs are again Western Germany and Italy; the United Kingdom is the most important market for Ghana Lumber (Table 21).

Other countries that import Ghana timber are the United States, Eire, Finland, China, Japan, New Zealand, etc; and some timber deficient countries in Africa. The United States imports about 8-10% of the total lumber production in Ghana. The African market for Ghana timber is relatively undeveloped. Many factors have contributed to this. Among them are:

(i) The attractions of the European and United States markets in the form of machinery and equipment, and

(ii) Financial complications affecting foreign exchange transactions between Ghana and those African countries that may import timber.

2.5.4.2 <u>Market Structure</u>

The market for Ghana timber operates at four levels, namely,

TABLE 22 - Royalty Rates for Economic Species in Cedis

SPECIES	ECONOMIC CLASS	ROYALTY RATE PER TREE IN ¢
Chlorophora excelsa	Ia	¢16
Entandrophragma angolense	"	6
Entandrophragma cylindricum	"	16
Entandrophragma utile	"	12
Khaya anthotheca	"	16
Khaya grandifoliola	"	16
Khaya ivorensis	"	16
Mimusops djave	"	10
Nauclea diderrichii	"	8
Pericopsis elata	Ib	28
Lovoa trichilioides	"	8
Terminalia ivorensis	"	8
Triplochiton scleroxylon	"	8
Tarrieta utilis	Ic	8
Entandrophragma candollei	IIa	8
Guarea cedrata	"	8
Guarea thompsonii	"	8
Lophira alata	"	8
Piptadeniastrum africanum	"	6
Antiaris africana	IIb	6
Mansonia altissima	"	6
Nesogordonia papaverifera	"	6
Turreanthus africanus	"	6
Guibourtia ehie	"	6
Others		6

$1(Aust.) = ¢1.57 (march 1975).

(SOURCE: W.P. Records, Ghana)

(i) The Stumpage market,

(ii) The Lumber market,

(iii) The Veneer and Plywood market,

(iv) The retail market for lumber, veneer and plywood.

The Structure of the Stumpage Market

The Stumpage market itself operates at two levels, namely,

(i) The Royalty Market, and

(ii) The Sawlog Market.

At the Royalty Market timber is sold in the form of untouched standing trees at fixed royalties (Table 22) by the Forestry Department in the case of Forest reserves, and by the Lands Department in unreserved forests. The buyers are the sawlog producers (sub-section 2.5.3.1). The royalties are fixed by law and the current rates have been in operation for at least 10 years. The royalties are the same for the same species irrespective of size and location. The royalty market in effect represents a situation in which both supply and demand are perfectly elastic.

The Sawlog Market can be divided into two, i.e.

(i) The Market for Local mills, and

(ii) The export market.

The lower grade of sawlogs which have many natural and seasoning defects such as eccentric heart, double heart, bends, bumps, flütes, knots, ingrown bark, heart rot, ring shakes, cup shakes, radial shakes, star shakes, etc, go to the local mills. The veneer and plywood mills absorb the slightly better material out of this and the rest of the sawlogs go to the sawmills.

There are about six large and efficient mills with considerable economies of scale. These mills are jointly owned by the Government of Ghana and some West European firms, and at least three of these mills produce both veneer and plywood as well as lumber. These large mills produce their own sawlogs from concessions owned by them (sub-section 2.5.3.1), but they also augment their own production by the purchase of a proportion of their sawlog requirements from the large number of Ghanaian Sawlog Producers.

The rest of the poor grade of sawlogs goes to small sawmills belonging to Ghanaians, Syrians and Lebanese. The Syrians and Lebanese normally do not own timber concessions, and they must buy all the sawlogs consumed in their sawmills. However, these Syrians and Lebanese as well as the firms operating the large mills may own the plant and equipment used, in felling and extraction and transportation of sawlogs to the mills, by the Ghanaian sawlog producers. The millers are therefore able to buy sawlogs at their own prices. Since each mill buys sawlogs from a set of producers using plants and equipment owned by the mill, the millers individually represent monopsonists.

The export market for sawlogs is the more important since it is restricted to the better grade of sawlogs.

All sawlogs are carefully inspected by the producers and up to 20% of the trees felled may be considered as worthless and therefore left in the forest to rot (Table 13 records some non-utilizable volumes). At the sawlog market the sawlogs are further inspected by the Forestry Department and only the best grades of sawlogs, ie. grades I and II, depending on the natural characteristics of the species, are passed as suitable for export in the log form. Since these export logs represent about 40% of the total utilizable volume of sawlogs, they in effect represent about 32% of the total timber volume cut in the forest. The firms which own the large mills export sawlogs to their parent companies in Western Europe. These efficient firms may have strong links with the West African Conference Lines (The Shipping Syndicete that controls sea cargo movements between Western Europe and West Africa) and export of sawlogs may not be a great problem.

The large numbers of small Ghanaian firms which produce sawlogs sell export sawlogs to the "Resident Buyers". The resident buyers are experienced businessmen who are the local representatives of firms usually based in Western Europe; they may each purchase export sawlogs in one country or within the West African region. These resident buyers are kept well imformed about production levels and pricing of sawlogs in the Ivory Coast, Cameroon, Nigeria, Gabon, Congo Brazzaville, Zaire and Ghana. They are also up-to-date with market conditions in Western Europe at any one time, cargo ship movements between West African ports and countries overseas, and the levels of stockpiles of sawlogs in their own countries; and they are able to manipulate the sawlog markets of West Africa to their own advantage.

Prices of sawlogs may vary from about ¢20 ($13 Aust.) per metric ton to about ¢120 ($76 Aust.) per metric ton depending on species, grade and market conditions. Prices are negotiated between the individual Ghanaian producer and the resident buyers, and even though the demand for tropical hardwoods is high, yet a kind of oligopolistic interdependence exists among the resident buyers to ensure that prices are kept to the minimum and do not rise beyond certain levels at any one time. The Ghanaian producers of export sawlogs operate on small family basis and maintain little contact with other producers, though they all belong to an industry association. The initial capital outlay of these firms, individually, may be very small, and liquidity problems are common. There is virtually no market intelligence, and no forward planning. Under these conditions these Ghanaian producers of export sawlogs cannot influence prices to any extent. Each of these many Ghanaian firms produces a small proportion of the total demand of the best quality export sawlogs and, in effect, operates on a perfectly competitive market.

The Structure of the Sawn Timber Market

The Sawn timber (lumber) market also operates at two levels, that is,

(i) The Local Ghanaian Sawn Timber Market, and

(ii) The Export Market for Sawn Timber.

Overseas buyers of Ghana lumber place orders quoting prices and specifications. As far as the large sawmills are concerned such orders may come from parent companies overseas. If the sawmiller accepts the orders the lumber is produced and the best grades (sub-section 2.5.3.2) are sold to the export market.

In general the buyers overseas are well-informed about market conditions in their countries, and they indirectly dictate the prices. Because of the strong backward linkage of the industry as a whole the sawmillers may depend on the overseas buyers for the supply of plant and equipment for the sawmills. Under such conditions the buyers can impose further pressures on the saw-miller. An unfair business alliance can thus arise between the overseas buyer and the sawmiller; but the effects of such alliances may be minimised by the Ghana Timber Marketing Board (GTMB), which must first approve overseas orders before shipments can be made.

The Local Ghanaian Sawn Timber Market absorbs the lumber that is usually unsuitable for export.

At this market the behaviour of the sawmiller changes. He is in constant contact with retailers who queue at the sawmills and literally beg for supplies of fresh green lumber from the production lines. Competition on the part of the sawmillers is virtually absent, and these sawmillers dictate the prices of lumber which are unnecessarily high. If the powers of the sawmillers, individually, are aggregated, then they constitute a monopoly power.

The Structure of the Veneer and Plywood Market

The local as well as the export markets for veneer and plywood are small compared with the sawlog and lumber markets. It is in the veneer and plywood markets that quality differentiations begins to emerge (sub-section 2.5.3.3). The quality differentiation encourages competition which is perhaps not intended to force any manufacturer out of the export market, but to help improve the quality of the local products so that they can compete in the overseas markets with similar products made from imported Ghana or West African sawlogs. The few producers of veneer and plywood in Ghana and other West African countries are also well informed about market conditions overseas, and they are able to achieve an oligopolistic interdependence and not price themselves out of the overseas markets.

The Local Ghanaian Market for veneer and plywood is different from that of lumber in that well established local retail companies with considerable business experience buy the veneer and plywood from the manufacturers. The manufacturers are happy to get rid of poorer materials and the buyers ensure that the veneer and plywood are purchased at reasonable prices so that they can make a small profit at the retail market.

The Structure of the Retail Markets

The retail markets affect the sale of lumber, veneer and plywood to consumers of those products in Ghana and abroad.

In the overseas markets the oligopolistic interdependence of the few dealers of tropical hardwoods is likely to ensure advertising by all, price fixing and profit maximization.

In the Local Ghanaian markets retailers, usually shrewd Ghanaian women and some Upper Volta nationals resident in Ghana, sell lumber of all sizes in open markets to the Ghanaian public. In addition the sawmills make direct sales to consumers. The demand for sawn timber is high and both the sawmillers and the retailers are aware of this. The buyer has no choice but to accept a large amount of poor lumber and to rely on the ingenuity of carpenters. Most of the lumber goes to dwelling construction; however, the furniture market absorbs a substantial amount of this. Prices are determined by the sawmillers and the retailers who as a group constitute monopoly power.

Unlike the lumber market, prices on the veneer and plywood market are consistent and consumers get a reasonable amount of satisfaction.

2.5.4.3 Supply and Demand Situation for Tropical Hardwoods

The two most important regions in terms of tropical timber consumption are Western Europe and North America. Both regions consume over 70% of the total world production of plywood, and it has been estimated that between them the two regions will consume about 27.5 million M^3 of veneer and plywood in 1975; demand in the aggregate of tropical hardwood lumber, veneer and plywood and other wood-based panel products for 1975 is estimated at 32-37 million M^3 as against 17 million M^3 consumed by the world in 1961 (FAO, 1967). This consumption rate of tropical hardwoods represents an exponential growth rate of approximately 5% per annum.

It has also been estimated that during the decade 1975-1985 the demand for tropical hardwoods will increase by 45% (Lorensen, 1973).

The results of the high demand for tropical hardwoods have been increases in exports of sawlogs, sawn timber and veneer and plywood to Western Europe by West Africa and Malaysia (the

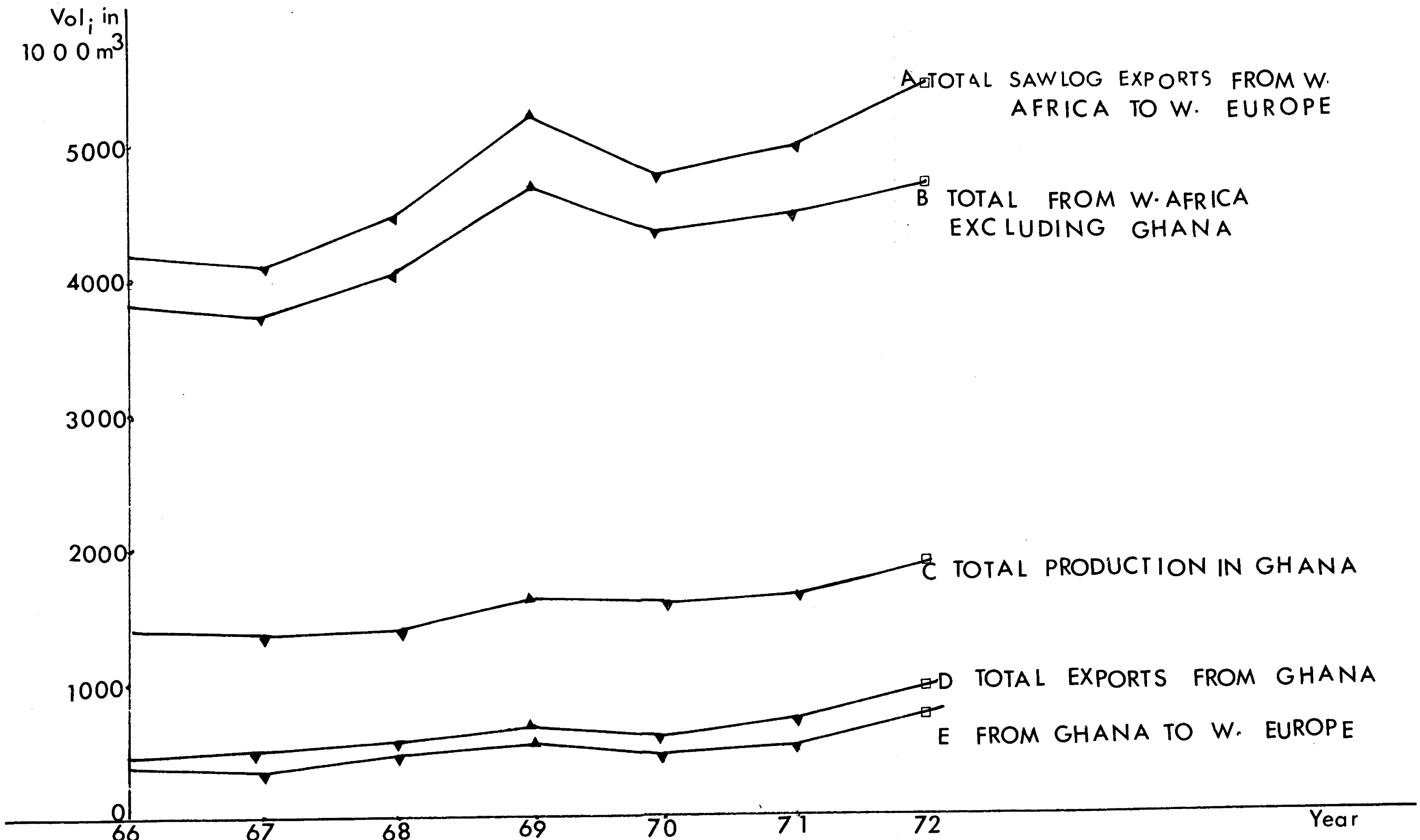


FIG 13 SAWLOG EXPORTS FROM WEST AFRICA

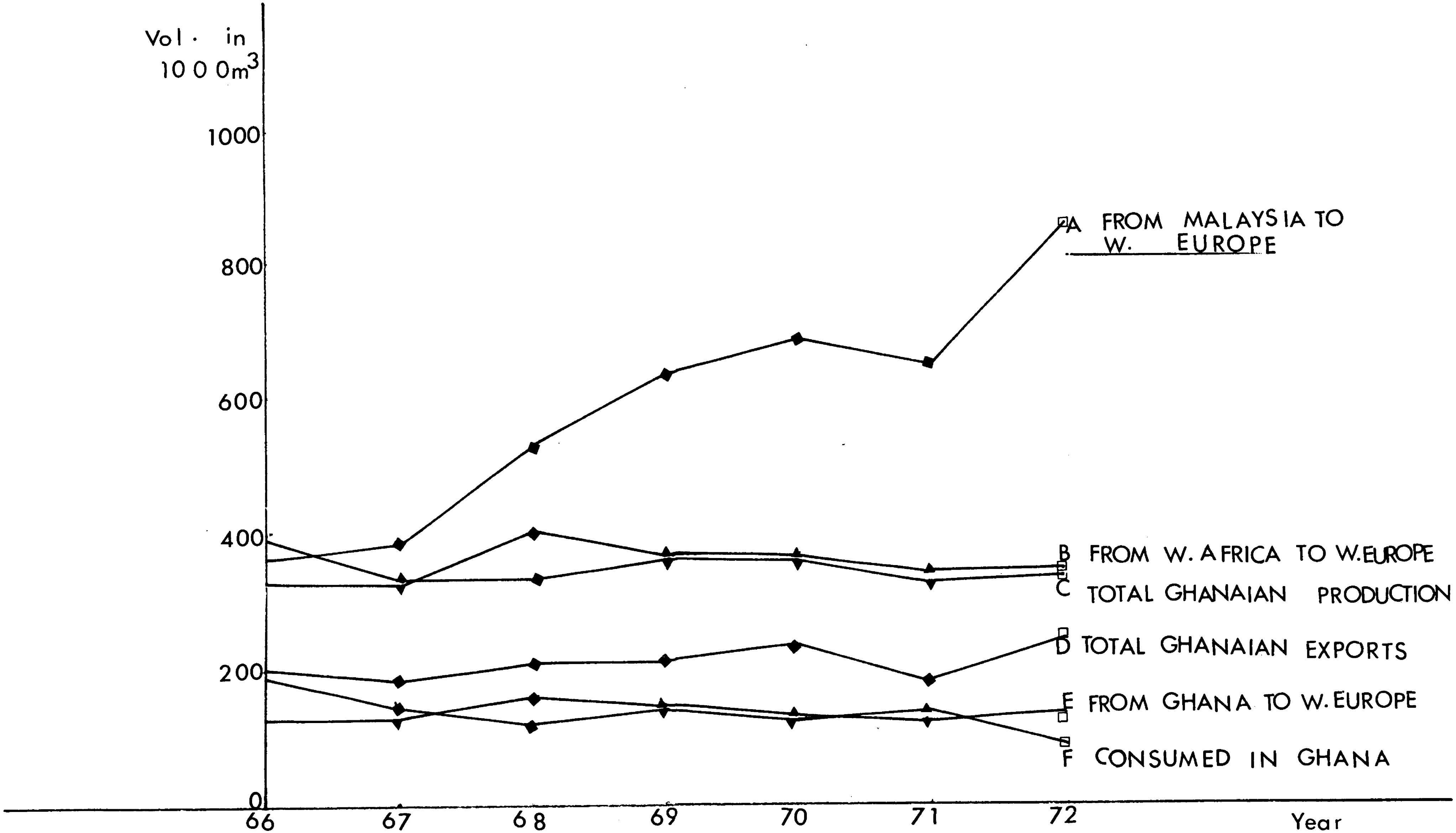


FIG. 14 SAWNWOOD PRODUCTION AND CONSUMPTION

largest single supplier of tropical hardwoods during the seven year period from 1966 to 1972 (Figures 13,14). Sawlog supplies to Western Europe by individual countries in West Africa, except for supplies by Nigeria, Zaire and Congo Brazzaville, have gone up during the period (Table 20). The Ivory Coast and Gabon have recorded the largest exports of sawlogs to Western Europe, and both countries are yet to reach their peak export levels.

Malaysia more than doubled exports of sawn timber to Western Europe between 1966 and 1972 (Table 20 and Figure 14). The large increase in supplies by Malaysia must have been partly accounted for by the discontinuation by Malaysia of hardwood sawlog exports since 1970, and perhaps partly by increased investments in sawmills. No significant increases in sawn wood exports to Western Europe by West Africa took place during the period. Generally poor investments in the sawmilling industry in the West African region must have accounted for this.

In Ghana increases in exports of sawlogs occured during the period of seven years (Tables 18, 20 and figure 13).

Sawn wood production have generally reached a plateau, andbecause of the high demand for sawn timber both in Ghana and abroad there have been strong competition between the relative quantities of sawn timber consumed in Ghana and abroad (Table 14).

Veneer and Plywood production in Ghana, though small, have shown the largest increases during the seven year period. Production increased from 21,560M^3 in 1966 to 46,910M^3 in 1972. This increase represents an exponential increase of 12% per annum.

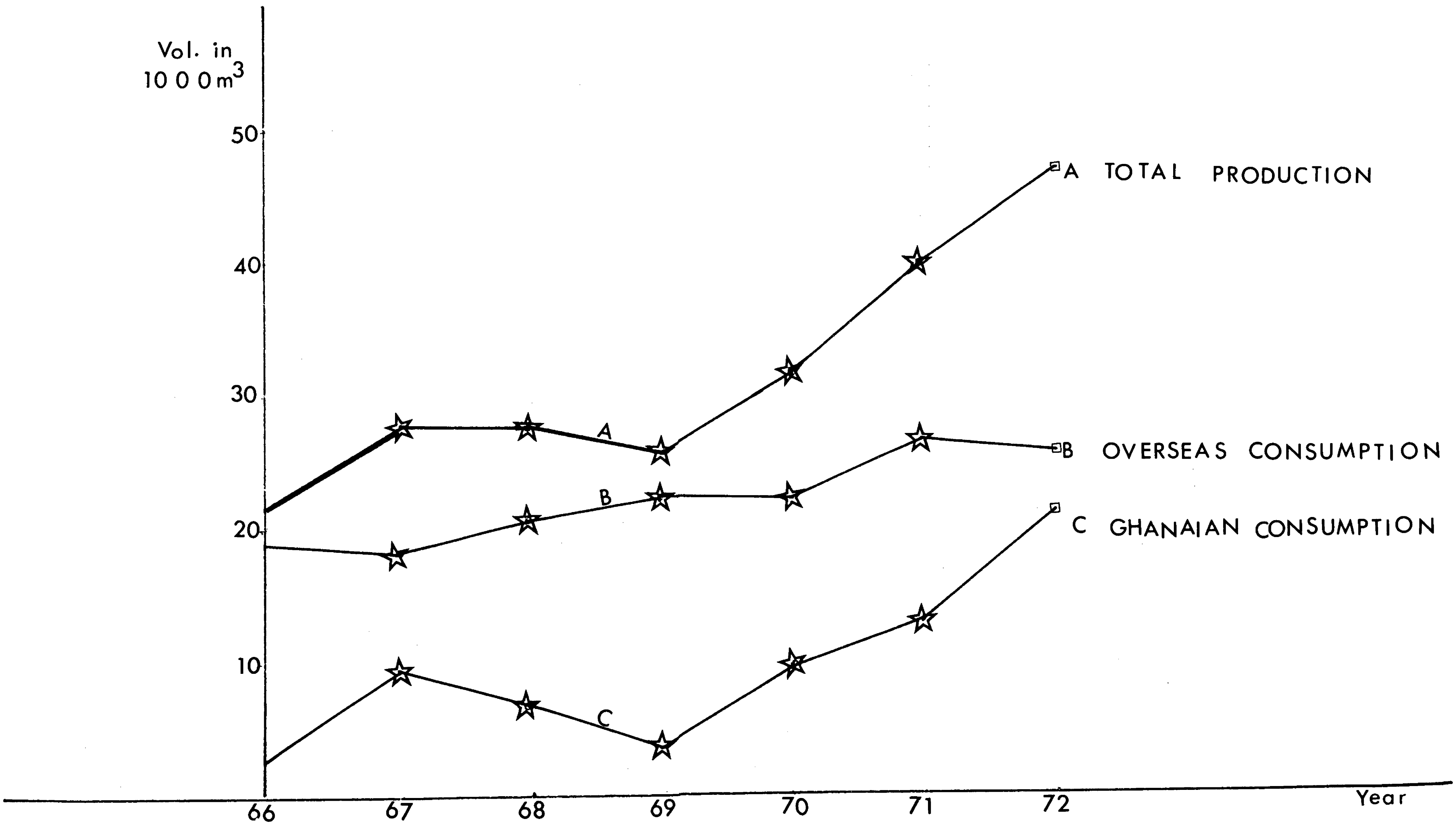


FIG.15 VENEER AND PLYWOOD PRODUCTION AND CONSUMPTION

TABLE 23 - Ghanaian Log Supply of Major Species to Countries Overseas in 1000 M^3 and Respective Prices per M^3 in Cedis

YEAR	E. CYLINDRICUM		E. UTILE		MIMUSOPS DJAVE		KHAYA SPP.		T. SCLEROXYLON		P. ELATA		TOTAL/PRICE/UNIT	
	QUANTITY	PRICE	QUANTITY	PRICE	QUANTITY	PRICE	QUANTITY	PRICE	QUANTITY	PRICE	QUANTITY	PRICE	QUANTITY	PRICE
1966	29.37	57.22	55.21	43.09	28.25	48.39	35.45	44.85	170.02	20.48	6.82	91.83	325.12	50.98
1967	30.58	51.92	61.11	46.62	27.10	44.15	39.82	40.62	189.38	18.37	5.99	72.41	353.98	45.68
1968	40.27	64.28	62.84	53.69	25.96	50.51	34.00	43.80	226.13	20.84	10.48	83.00	399.68	52.68
1969	45.15	74.17	76.37	67.46	23.59	51.57	42.03	52.98	270.44	24.72	18.47	93.78	476.05	60.78
1970	39.09	69.93	50.40	61.81	28.22	55.45	34.77	53.69	236.83	22.96	16.20	104.55	405.51	61.40
1971	43.84	66.40	70.77	56.51	24.08	50.51	40.30	45.92	311.61	22.60	10.52	96.78	501.12	56.45
1972	53.22	96.07	103.09	93.24	32.76	79.12	59.72	63.92	409.18	34.61	14.58	145.52	672.55	85.41
TOTAL	281.52	-	479.79	-	189.96	-	286.09	-	1813.59	-	83.06	-	3134.01	-
MEAN	40.22		68.54		27.14		40.87		259.08		11.87			

(SOURCE: Annual Reports of the Forestry Dept, Ghana; Ghana Govt and Report of the Salary Review Committee 1974)

TABLE 24a Ghanaian Sawnwood Supply of Major Species to Countries Overseas in $1000M^3$ and Respective Prices/M^3 in Cedis (¢)

Year	E. cylindricum		E. utile		Khaya Spp.		Mimusops djave	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Price
1966	24.90	59.34	36.97	65.34	32.69	60.04	5.94	55.10
1967	23.72	49.09	37.67	57.92	26.55	55.10	5.61	48.39
1968	30.01	51.92	28.79	70.64	22.82	61.81	6.89	49.45
1969	24.90	65.70	30.43	93.24	23.89	72.41	5.45	56.51
1970	23.47	79.12	30.85	98.54	45.65	39.91	5.35	61.81
1971	18.64	68.87	34.34	77.35	13.86	73.82	5.14	62.87
1972	65.26	38.15	33.14	129.62	21.10	93.60	5.34	90.07
TOTAL	210.90	-	232.19	-	186.56	-	39.72	-
MEAN	30.13		33.17		26.65		5.67	

(Source: Annual Reports of the Forestry Dept., Ghana)

TABLE 24b Ghanaian Sawnwood Supply of Major Species to Countries Overseas in 1000M^3 and Respective Prices/M^3 in Cedis (¢)

Year	T. scleroxylon		P. elata		Chlorophora		Total/P/Unit	
	Quantity	Price	Quantity	Price	Quantity	Price	Quantity	Av.
1966	38.03	41.68	19.87	99.60	1.70	56.87	160.1	62.57
1967	32.49	38.50	13.33	80.53	10.35	49.45	149.72	54.14
1968	38.09	40.26	17.29	105.25	23.14	50.15	167.03	61.35
1969	44.38	46.62	17.72	126.80	30.13	58.98	176.9	74.32
1970	44.10	49.80	21.23	154.35	26.41	60.75	197.06	77.75
1971	36.34	47.33	13.44	114.08	26.75	59.34	148.51	71.95
1972	37.09	66.75	10.84	180.13	34.76	91.48	207.53	98.54
TOTAL	270.52	-	113.72	-	153.24	-	1206.85	-
MEAN	38.64		16.25		21.89			

(Source: Annual Reports of the Forestry Dept., Ghana)

Exports of veneer and plywood increased during the period. Consumption of veneer and plywood in Ghana, which has remained low for a long period, more than doubled during 1970–1972 (Figure 15), and thus adversely affected the quantity exported. This is a sign that the future increases in demand for tropical hardwoods may equally affect the affluent world and the poor countries that produce them.

Export of sawlogs for the main export timber species of Ghana such as Entandrophragma cylindricum, E. utile, Khaya spp., Triplochiton scleroxylon and Pericopsis elata went up in the period 1966–1972 (Table 23). Exports of sawlogs of Triplochiton scleroxylon and Pericopsis elata were then doubled between 1966 and 1972. There was not much increase in the annual export of Mimusops djave. Sawn timber exports for the main export species remained fairly stable during the period except for the exports of Entandrophragma cylindricum and Chlorophora excelsa in which increases were recorded. Sawn timber exports of Chlorophora excelsa increased from 1700M^3 in 1966 to 34760M^3 in 1972 (Table 24). This increase amounted to an exponential increase of 54% per annum. The significant increase in the export of sawn Chlorophora excelsa was due to the lifting of the ban on the export of this species.

There were generally price increases of both sawlog and sawn timber exports of the important export species from Ghana in 1966–1972 (Tables 23, 24), but it is difficult to explain whether the increases were real or they were merely adjusted increases to take inflation into account.

Despite the high demand for tropical hardwoods, sawlog and lumber export patterns of West African timber reveal the existence of short run trade cycles of three to four years duration (figures 13 and 14). The component parts of the trade cycles are as follows:

RECESSION	TROUGH	EXPANSION	PEAK
1966–1967	1967	1968	1969
1969–1970	1970	1971	1973 •
1974	1975	1975/76	1976 *

• Confirmed by personal communication.

* Estimated from past trends.

The recession in 1974–1975 could last longer than usual because of the oil crisis and the accompanying economic recession of the Western economies. Many factors account for the occurence of the trade cycles. Among them are:

(i) Fluctuating weather conditions in West Africa which affect logging and shipments;

(ii) Stock-piling of hardwood sawlogs in Western Europe, especially in Western Germany, France, Italy, United Kingdom, etc.

One can well understand the necessity for stock-piling by mills in Western Europe. The materials from West Africa take several weeks to be transported by ships from the countries of origin. This transport lag can aggravate stock levels and market conditions.

It appears that the resources of tropical hardwoods are

TABLE 25: Tropical Hardwood Timber Resources of the World

REGION	AREA OF HARDWOOD FOREST IN MILLION HECTARE	ESTIMATED VOLUME OF GROWING STOCK PER HECTARE IN M^3	TOTAL EXPLOITABLE TIMBER IN 1000 MILLION M^3 (2x3)	% OF TOTAL EXPLOITABLE VOL. IN CURRENTLY ACCEPTABLE SPECIES	ESTIMATED VOL. OF CURRENTLY ACCEPTABLE SPP. IN 1000 MILLION M^3 (4x5)
1	2	3	4	5	6
Asia Pacific	488	84	41	30%	12.3
Africa	667	45	30	15	4.5
Central and South America	838	185	155	10	15.5
TOTAL	1993	-	226	-	32.3

(SOURCE: FAO-World Forest Inventory, 1963) equally high to be able to meet the high demand for tropical hardwoods. FAO forest inventory results in 1963 (Table 25) indicate that only about 14% of the total exploitable timber resources in the tropics are currently accepted on the timber market. A full utilization of the vast resources may maintain the markets for hundreds of years.

In Ghana the stocking of about 200M^3 per hectare of merchantable species over an area of over 2 million hectares can yield about 400 million M^3 of timber.

In Ghana and perhaps in other tropical countries the problems may not be one of meeting rising demands, but of ensuring that the forest resources are judiciously employed to meet economic as well as biological, ecological, and environmental needs.

2.5.4.4 Forecasts of Supply and Demand for Ghana Timber

It is difficult to base forecasts of future production and consumption of Ghana timber on macroeconomic factors such as population growth and GDP per capita because of:

(i) the importance of foreign exchange earnings to Ghana from timber exports,

(ii) The strong competitive position of cement as a substitute material for timber in Ghana.

For instance, the actual consumption of sawn timber in Ghana in the early 1960s was 0.018M^3 per caput and it was increasing at an exponential rate of 1.1% per annum. The estimated consumption for 1970 based on this increase was 0.02M^3 per caput (Danso, 1966). In fact this turned out to be 0.014M^3 per

TABLE 26 - Results of Regressions Using Data in Table 18.

DEPENDENT VARIABLE, Y	INDEPENDENT VARIABLE, X	LEAST SQUARES FORMULA	STANDARD ERROR	CONFIDENCE INTERVAL AT 95% LEVEL	t-TEST FOR REGRESSION COEFFICIENT B AND ITS SIGNIFICANCE LEVEL	F AND THE R^2 SIGNIFICANCE LEVEL
Percentage Contribution of Forest Reserves to Total Sawlog production	Total sawlog production	$Y^1 = -27.77 + .047X$	7.47	± 15	2.90 at 95%	22.83 at 99% 77
Total Production of Veneer, Plywood and sawn timber	Mill intake	$Y^1 = 142.39 + .27X$	17.28	± 34	1.96 at 80%	3.8 at 80% 44
Veneer and Plywood Export	Total Veneer and Plywood Production	$Y^1 = 11.98 + .32X$	1.8	± 4	3.79 at 99%	17.00 at 99% 77
Local Consumption of Sawn timber in Ghana	Sawn Timber Exports	$Y = 297.58 - .74X$	25.8	± 51	1.69 at 80%	2.92 at 80% 37

(Source: Simple regression analyses by L.K. Danso)

N.B: The results indicate that there are linear relationships between the dependent and the independent variables, and that the independent variables contribute in explaining the variations in the dependent variables.

caput. The population growth was maintained at 2.5% per annum, but sawn timber consumption in Ghana did not keep pace with the population increase. Declining real incomes could have contributed to to this.

An attempt was made to relate the forecasts to total timber exports from other West African countries and Malaysia, dwelling construction in Western Europe, and the volumes and prices of the major export species, but the data collected for the short period from 1966 to 1973 could not produce any meaningful regressions. The alternative approach was to base the estimated forecasts on past trends, making use of regressions of selected data in table 18. The results of the four separate simple regressions have been displayed in Table 26.

The following assumptions have been made on the forecasts based on the regressions:

(i) that the theoretical values of the dependent variables at 95% confidence interval bear linear relationships with the years of production, extrapolated to year 2000;

(ii) that the equivalent values of the independent variables can be calculated from the extrapolated values of the dependent variables;

(iii) that medium forecasts are represented by the actual extrapolated values of the dependent variables, high forecasts by the upper confidence limits of the dependent variables, and low forecasts by the lower confidence limits of the dependent variables;

TABLE 27 Forecasts of Production and Consumption of Timber in $1000M^3$

		Remarks	No.	1980	1985	1990	1995	2000	1980	1985	1990	1995	2000	1980	1985	1990	1995	2000
	Population in Ghana in Million	2.5% Annual Growth Rate	1	11.25	12.72	14.30	16.29	18.43	11.25	12.72	14.30	16.29	18.43	11.25	12.72	14.30	16.29	18.43
	GDP per capita in $(US)	0.8% Annual Growth Rate	2	290	302	313	326	340	290	302	313	326	340	290	302	313	325	340
				H I G H					M E D I U M					L O W				
	Per capita consumption of sawn timber		3	0.017	0.015	0.013	0.012	0.010	0.012	0.0110	0.0098	0.0086	0.0076	0.0079	0.007	0.006	0.0055	0.0048
	Per capita cons. of Veneer & P'wood		4	0.0048	0.0055	0.006	0.006	0.0064	0.0048	0.0048	0.0054	0.0058	0.006	0.0033	0.0042	0.0048	0.0052	0.0065
Sawlog Production	TOTAL		5	2346	2580	2719	2719	2719	2027	2261	2484	2708	2719	1708	1942	2165	2389	2399
	From Forest Res. Reserves	Derived from Line 7	6	1936	2412	2719	2719	2719	1358	1775	2211	2695	2719	897	1233	1602	2019	2039
	% Contribution by Forest Reserves		7	82.5	93.5	100.0	100.0	100.0	67.5	78.5	89	99.5	100.0	52.5	63.5	74	84.5	85
Prod. of P'sed Wood	Sawn Timber		8	348	335	325	313	301	326	316	304	291	279	305	294	262	270	257
	Veneer & Plywood		9	97	120	144	169	191	85	108	131	156	179	72	96	119	143	167
	TOTAL		10	445	455	469	481	492	411	424	435	447	458	377	390	401	413	424
Exports	Sawlog	Der. from Lines 5 & 14	11	1225	1412	1509	1465	1424	1032	1218	1400	1580	1550	839	1025	1207	1387	1356
	Sawn Timber	Der. from Lines 8 & 15	12	157	147	134	122	110	186	176	164	151	139	216	205	193	181	168
	Veneer & Plywood		13	43	50.5	58	66.8	73.2	39	46.5	54	61.8	69.2	35	42.5	50	57.8	65.2
Local Wood Consumption	Sawlog intake in Local Mills		14	1121	1168	1210	1254	1295	995	1043	1084	1128	1169	869	917	958	1002	1043
	Sawn Timber		15	191	191	191	191	191	140	140	140	140	140	89	89	89	89	89
	Veneer & Plywood	Der. from Lines 9 & 13	16	54	69.5	86	102.2	117.8	46	61.5	77	94.2	109.8	37	53.5	69	85.2	101.8
		Der. from Lines 10 & 14	17	60.30	60.79	61.24	61.64	62.00	58.89	59.35	59.87	60.37	60.82	56.61	57.47	58.14	58.78	59.35

(iv) that past trends continue;

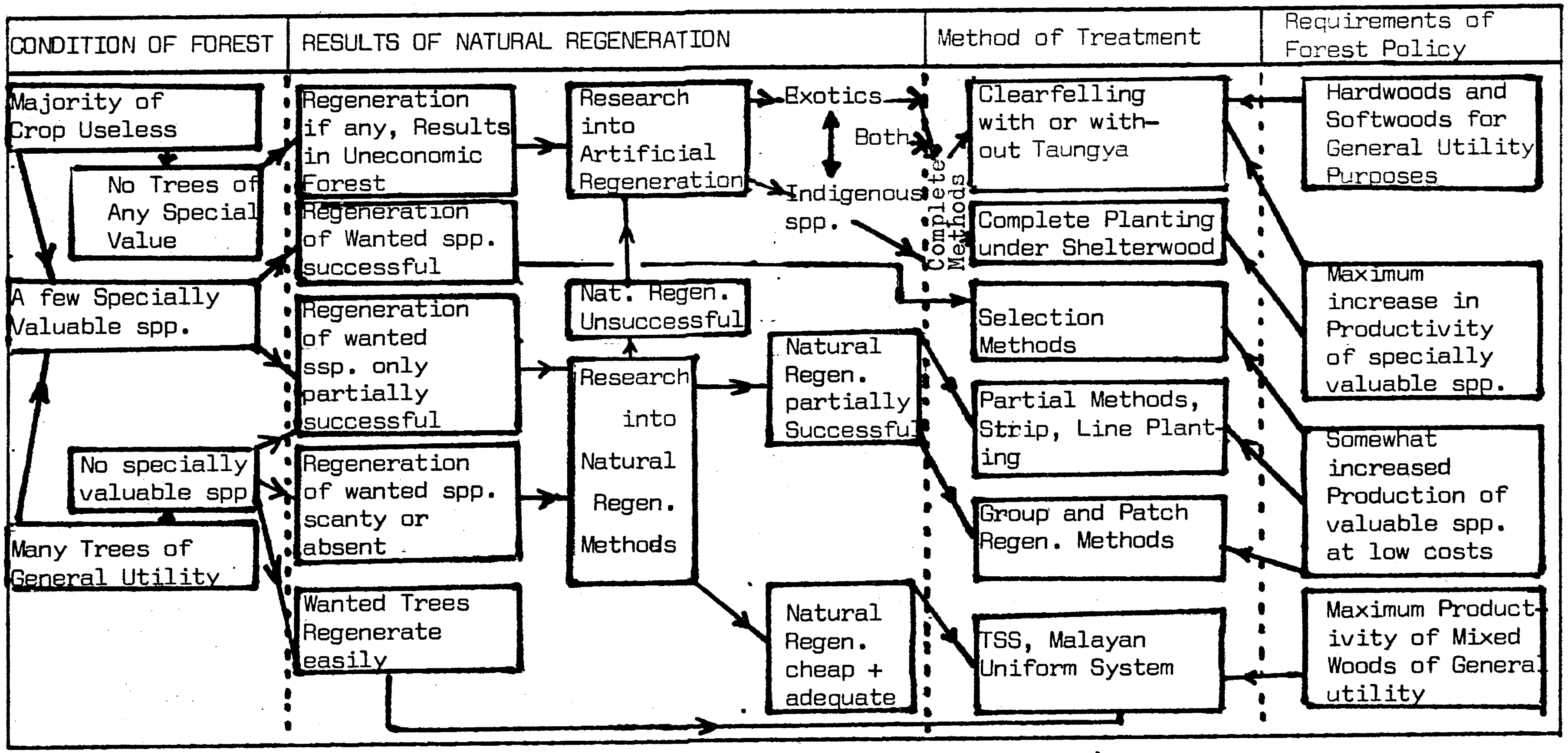
(v) that there will not be any unanticipated technological changes affecting the production of timber;

(vi) that there will not be any drastic changes in forest policy;

(vii) that there will be no wars or catastrophe during the period covered by the forecasts.

From assumptions i-iii the forecasts of production, exports, and local consumption in Ghana have been estimated (Table 27). There are dangers in forecasts based on past trends since some trends may not be repeated to year 2000. One important factor that is likely to continue is the need for foreign exchange; the importance of this will determine the relative quantities of timber exports and local consumption. If investments in sawmilling continue to be low, then the past levels of sawn timber production will continue into the future, and waste in milling will go up. However, it is hoped that new investments and improved technologies can lead to increases in the estimated levels of sawn timber production. Any new investments should absorb some of the sawlog exports so that the actual estimated levels of sawlog production may be maintained.

TABLE 28 – Schematic Diagram of Regen. Methods in the Wet Tropics



(SOURCE: Modified from Lecture Notes by H.C. Dawkins)

PART II

CHAPTER 3

MANAGEMENT OF THE GTHF

This section deals with the general approach to forest management in the wet tropics, the methods of silvicultural management that have been tried in the GTHF, and the direction of forest research programme to ensure the success of forest management.

3.1 GENERAL APPROACH TO MANAGEMENT OF TROPICAL HIGH FORESTS

Methods of management of wet tropical high forests such as the GTHF are chosen after a careful study of:

(i) the complex biological and ecological characteristics (Chapter 2),

(ii) the results of previous research on forest management, and

(iii) the demands of the forest policy.

The flow-chart, briefly describing the essential features of such a study and the methods of management that may be applied, appears in Table 28. Most of the methods listed have been tried in Ghana. However, as for many tropical areas the methods of management that balance the requirements of ecological, biological and sociological factors are yet to be found. Such methods of management may be evolved from those already applied to the GTHF and described in this section under:

TABLE 29 - Summary of Operations Under the Polycyclic System

ACTION	REMARKS
5% Enumeration Survey	
Yield Calculation	Based on results of the above survey and assumptions on times of passage and 25% mortality of existing trees during time of passage.
100% Survey of Economic Species + Selective Thinning	Preparation of stock maps showing numbers of all economic trees 5ft. girth and above. All economic trees under 5ft. girth selectively thinned.
Yield selection	Done from stock maps. Should normally ensure fair distribution of future timber trees.
Payment of Advances by Concessionaire	Based on the total amount of royalties payable. Road alignments, loading stations agreed upon with District Officer.
Receipt of Selected Yield and Permit by Concessionaire	
Felling and Extraction of Yield (logging)	Concentrated in compartments. Permits cancelled when felling and extraction in a compartment are complete.

(SOURCE: From Personal Experience)

(i) Polycyclic systems

(ii) Monocyclic systems.

3.2 FOREST MANAGEMENT OF THE GTHF UNDER THE POLYCYCLIC SYSTEM

Under the polycyclic system of silvicultural management the productive portion of the working plan area is divided into a number of annual coupes each of which should give a sustained yield in a cyclical cutting. In Ghana the annual coupe may comprise one or several compartments depending on the size of the production working circle, the stocking density, the proportion of economic trees 11ft. girth and above (all of which are considered over-mature), and the global annual production target. The felling cycle for each annual coupe has in the past been 25 years.

Several forest operations are undertaken to ensure an orderly sequence of fellings and the success of natural regeneration (Table 29). The selective thinnings (mentioned in the table) have taken the form of poisoning with sodium arsenite all trees within a radius of 9ft. from the favoured economic trees below 5ft. girth, as well as the removal of competing climbers. Currently, however, the thinning operations have been suspended because of the deleterious effect of sodium arsenite on man, wildlife, the favoured trees, etc; moreover, doubts have been expressed as to the efficacy of the thinnings. In some areas the favoured trees have had their tops lopped off as a result of a sudden exposure to the elements. By the time the thinning operations were suspended (1970) over 0.64 million acres (0.26 million ha.) of tropical forests had been selectively thinned using some 3700 drums of sodium arsenite.

At logging (also listed in Table 26) removals are based on a calculated yield. This calculated yield has in the past been usually achieved by the removal of:

(i) all class Ia trees 13ft. girth and above,

(ii) at least 10% of all class Ia trees in the 11-13ft. girth, and

(iii) varying proportions of class Ib and Ic trees 9ft. girth and above and class II trees 7ft. girth and above, depending on the demand for the particular species in these economic classes.

In 1970 an argument was advanced regarding overmaturity of natural forest trees in Ghana (Annin-Bonsu, 1970). Based on this argument a decision was taken to fell all economic trees in production working circles to Minimum Exploitable Girths (MEG). These MEG are currently:

(i) 11ft. for all economic class I trees except Lovoa trichilioides, Terminalia ivorensis and Tarrietia utilis which may be felled at MEG of 7ft.,

(ii) 11ft. for all economic class IIa trees except Guarea cedrata which may also be felled at MEG of 7ft., and

(iii) 7ft. for all economic class IIb trees.

The felling cycle has now been fixed at 15 years instead of 25 years, and it is stipulated that at least 30% of the class I yield is to be removed from the class II trees (many of which are normally not felled). This current method of yield removal is, to a certain extent, a departure from the principles underlying the original application of the polycyclic system in Ghana - it assumes that all trees 11ft. girth and above are overmature; the size of the annual coupe has been increased at the same time as the removal per unit area has been increased. While the current practice will not represent a depletion of the GTHF, it will be necessary to watch the effects of sudden increases in production on the already carefully manipulated markets for Ghanaian timber.

The Polycyclic system has distinct advantages such as the maintenance of natural species distribution, very low risk of epidermics, good wood quality, low financial investment, protection of soil and water, conservation of native flora and fauna, etc.; however, it also has certain economic disadvantages - the species are slow growing; there is always the danger of creaming the GTHF because the removal of all the best looking economic trees with girths 11ft. and above can amount to the removal of the best phenotypes; only a few trees can be removed per hectare, and harvesting is sometimes inefficient.

3.3 MANAGEMENT OF THE GTHF UNDER THE MONOCYCLIC SYSTEM

The monocyclic silvicultural system aims at producing a forest crop that has a fairly even beginning and a definite end as a whole. It is the subject of alternative (ii) in section 2.5.2. The difficult methods tried include Assisted Natural Regeneration in the form of the Tropical Shelterwood System (TSS), Artificial Regeneration in the form of Enrichment Line

TABLE 30 – Sequence of TSS Operations

YEAR	WORK DONE
1	Seedling survey, Demarcation, Stock Survey, Climber cutting, First canopy opening.
2	Second canopy opening
3	First cleaning and assessment
4	Second cleaning
5	Third cleaning
6	Harvesting of merchantable timber trees
7	Climber cutting and coppicing of damaged regeneration.
10	Climber cutting, layout of sample plots.
12	Poisoning of all weed species 4ft. girth and above, all economic class I species 9ft. girthe and above and all economic class II species 7ft girth and above.
Subsequent operations	Measurement of sample plots annually, and periodic thinning of the regenerated crop.

(SOURCE: TSS in Ghana by Jack + Mooney)

Planting and Clear cutting with artificial regeneration.

3.3.1 The Tropical Shelterwood System (TSS)

The TSS involves a well planned aided natural regeneration in comparatively rich forests in the CTA and ACA, and it is aimed at producing a uniform crop.

The assistance given to the regenerations already on the ground takes the form of a series of canopy manipulations and tendings over a period of years (Table 30). The management of the TSS involves the concentrations of the various operations in one area of forest at a time.

The TSS was introduced in Ghana in 1946 because it had apparently been successful in the wet tropical forests of Malaysia and it had been introduced in Nigeria in 1944. A carefully manipulated canopy cover over the GTHF appeared to be a close approach to the way the forests regenerate in nature. Evidence presented in sub-section 2.4.5.5 confirms the importence of canopy density on growth of some economic species in the GTHF.

However the TSS tried in two forest reserves (Bobiri and Asenango Forest Reserves) gave some unexpected results - In successfully regenerated areas the vigorously growing trees were the Sterculiaceae represented by *Triplochiton sclerxylon*, *Mansonia altissima*, *Nesogordonia papaverifera*, *Sterculia rlinopetala*, etc. The highly priced economic species such as *Chlorophora excelsa*, *Entandrophragma cylindricum*, *E. utile*, *Khaya* spp., formed only 6-10% of the regeneration, and they invariably constituted the poorest looking trees, with very little chance of becoming a potential timber crop.

The regressions of growth and some of the forest parameters affecting growth (sub-section 2.4.5.5) have indicated that canopy density is perhaps a critical factor influencing the growth of the relatively fast growing species as well as some of the slower growing species. A canopy manipulation that meets the requirements for growth of these species does not necessarily meet those of the more highly priced groups of economic species which, in the GTHF, appear to develop best under natural conditions or conditions of minimal disturbance. In fact canopy openings artificially made may be detrimental to the growth of such highly priced species.

After 20 years of research work on the TSS it was found inappropriate because of the results it gave, and it was therefore abandoned.

3.3.3 Enrichment Line Planting

This method which was adopted to improve the density of stocking of poorly stocked portions of the GTHF, especially in the CLTA, was tried in the 1940s and 1950s, but it was discontinued in the early 1960s.

In Enrichment line planting two year old striplings of *Mimusops djave*, *Khaya ivorensis*, *Entandrophragma utile*, *E. angolense*, *E. candollei*, *E. cylindricum*, *Tarrietia utilis*, *Lovoa trichilioides*, were planted in cleared lines (6ft. wide) at 0.25 chain in the lines. The lines were one chain apart and parrallel to one another. A total area of 7120 acres (2848 ha) was planted mainly in two forest reserves (Ankasa and Subri Forest Reserves) in the CLTA.

After planting, cleaning and further canopy openings were done in the second and fifth years. However, the canopy manipulations did not achieve what was expected and many of the planted trees were chocked by weeds. The lines were difficult to manage, and accessibility was very poor. These factors contributed to the method being discontinued.

3.3.3 Clear Felling with Artificial Regeneration

Scattered plantings of various species such as *Terminalia ivorensis*, *Entandrophragma angolense*, *E. cylindricum*, *E. utile*, *E. candollei*, *Triplochiton scleroxylon*, *Khaya ivorensis*, *K. anthotheca*, *K. grandifoliola*, *Turreanthus africanus*, *Mansonia altissima*, *Pericopsis elata*, *Mimusops djave*, *Tectona grandis* and *Cedrela odorata* have been done in Ghana since the 1930s. The plantings which were established partly by the taungya method (agri-silvicultural method) covered some 30,000 acres (12,000 ha.) by 1969. The plantings were concentrated both in the GTHF and in the transition belt between the GTHF and the GSW.

Access to many of the planted areas has been a major problem and it is very difficult to estimate how much of the areas planted has been successful. In 1969 the Government of Ghana became convinced that Ghana could run short of timber in the future, and also that Forestry has an important role in rural development to which it was committed; a planting target of 12,800 acres (5120 ha.) per annum was set. Despite the difficulties of seed procurement, nursery establishment, and accessibility, an area of 5110 acres (2044 ha.) was planted up in 1969. This was followed by plantings

TABLE 31 Main Programme of Forest Research

TYPE OF RESEARCH	NATURE OF RESEARCH
Silvicultural Research	1. Natural Regeneration - Maintenance of TSS plots, growth measurements under natural forest conditions. 2. Plantation Research - (a) Establishment of plantations with fast growing native Sterculiaceae such as *Triplochiton scleroxylon*, *Mansonia altissima*, *Sterculia* spp.; and also other species such as *Terminalia ivorensis*. (b) Establishment of plantations with fast growing exotics such as *Tectona grandis* and *Cedrela odorata*. (c) Forest Genetics - Selection of plus trees of *Terminalia ivorensis*, *Triplochiton scleroxylon*, *Pericopsis elata*, for plantation work. (d) Pretreatment and storage of forest tree seeds. (e) Plantation Trials of selected species of softwoods for poles and pulp - Species being tried are *Pinus elliottii*, *P. taeda*, *P. radiata*, *P. caribaea*, *Cupressus sempervirens*, *C. glabra*, *C. macrocarpa*, *C. lawsoniana*, *Araucaria angustifolia*, *Eucalyptus citriodora*, *E. tereticornis*, *E. cadambae*, *E. gummifera*, *E. alba*, *E. pilularis*, *E. papuana*, *E. intermedia*, *E. miniata*, *E. punctata*.
Utilization Research	3. (a) Wood anatomy for microscopic examination of species. (b) Forest Entomology for the study of defoliators, borers, termites, etc. (c) Wood Chemistry - Investigation into the production of glues, charcoal research to improve yield, wood preservation with tanalith C, termex, etc.; production of volatile oils from Eucalypts and some native species; production of industrial chemicals from sawdust. (d) Mechanical Testing of lesser known species with the view to promoting their use.

(Source: Annual Reports of the FPRI)

of 4415 acres, 12,618 acres and 22,844 acres in 1970, 1971 and 1972 respectively. A steady improvement was made and by 1972 it had been possible to cover the planting deficits of the previous years. The species being tried are *Tarrietia utilis*, *Terminalia ivorensis* and *Cedrela odorata* in the CLTA, and *Triplochiton scleroxylon*, *Gmelina arborea*, *Tectona grandis*, *Mansonia altissima* and a small amount of Eucalypts in the other associations as well as in the transition between the GTHF and the GSW.

The CCF has firmly emphasized that plantings are to be concentrated in poorly stocked forest reserves mainly in the CLTA and in the ACA as well as in the transition area already referred to.

3.4 FOREST RESEARCH IN THE GTHF

Forest Research is done by the Forest Products Research Institute (FPRI) with its headquarters in Kumasi (in the CTA).

The FPRI was part of the Forestry Department, Ghana, but it was separated from it in October 1963, and it has since remained a semi-autonomous body in the Council for Scientific and Industrial Research (CSIR). However, it works closely with the Forestry Department.

Its main programme concerns silviculture and utilization research (Table 31). It issues periodic Newsletter on its activities, but it is early yet to obtain concrete results of its activities.

PART III

CHAPTER 4

BENEFITS GAINED FROM THE GTHF

This section deals with both the tangible as well as the intangible benefits some of which have been referred to in earlier sections. The benefits are mainly those directly affecting the rural areas in Ghana, those affecting Ghana as a whole and benefits to foreign countries buying timber from Ghana.

4.1 BENEFITS TO RURAL AREAS IN GHANA

Innumerable benefits result from the management of the GTHF particularly where selective felling is used. Among them are the following:

(i) Capital inflow: This is usually in the form of plant and equipment such as sawmill, veneer and plywood mill plants, cutlasses, timber trucks, caterpillers, diesel motors, winches, cables, power saws, etc. for preparation of the forest for felling and extraction of sawlogs and conversion into lumber, veneer and plywood. The periodic inflow of capital continues so long as the business flourishes. The capital inflow leads to:

(ii) Employment: Idle and able-bodied persons as well as those usually underemployed are offered

TABLE 32 Unadjusted Values of Exports and Local Consumption of Processed Wood in Million Cedis

Item / Year	1966	1967	1968	1969	1970	1971	1972	Total
Total value of Exports of Processed Wood – Mainly Sawn & Peeled Wood	12.5084	10.0946	12.9184	15.7577	20.2349	16.2920	24.3857	112.1917
Value of Local Sales of Processed Wood	20.2677	13.7974	10.2814	19.7066	34.0485	20.4237	7.3960	125.9213
Total Value of Out-turn of Processed Wood	32.7761	23.8920	23.1998	35.4643	54.2834	36.7157	31.7817	238.1130
No. of Man-days Employed in Millions	7.6017	7.1808	7.4710	12.7053	11.5452	11.9907	14.2623	72.7570
Estimated No. of Employees Assuming 300 Working Days per annum	25,339	23,936	24,903	42,351	38,484	39,969	47,541	

(Source: Annual Reports, Forestry Dept., Ghana)

TABLE 33 Revenue and Expenditure of Forestry Department in Million Cedis, and No. of Employees

Item / Year	1966	1967	1968	1969	1970	1971	1972	Total
Revenue, Predominantly from Royalties	0.4763	0.5238	0.4874	0.5268	0.6599	0.7381	1.1721	
Total Expenditure Directly Incurred on GTHF	1.1142	1.0537	1.2242	1.4581	1.7872	1.8635	3.3301	
Total Expenditure on Education (Local) and Headquarters	0.1351	0.1296	0.3698	0.2115	0.4739	0.320	1.2694	
No. of Employees Directly Employed on the GTHF	2,021	2,393	2,479	2,507	2,442	4,864	4,998	
No. of Personnel in Education & Headquarters (including Students)	196	196	194	158	148	198	259	
Total No. of Employees	2,217	2,589	2,673	2,665	2,690	5,062	5,257	

(Source: Annual Reports, Forestry Dept., Ghana)

TABLE 34 Unadjusted Values of Gross Exports, Gross Imports and Net Exports in Million Cedis (¢1.50 = $1.0 (Aust.))

Item / Year	1966	1967	1968	1969	1970	1971	1972	Total
Sawlog Exports	13.1088	12.6948	16.2577	24.5112	19.8754	20.5361	42.2916	149.2756
Sawn Timber Exports	11.9730	9.6630	12.2962	14.9630	17.0955	12.2170	21.1731	99.3808
Veneer & Plywood Exports	0.4912	0.3560	0.5350	0.6999	3.1196	4.0578	3.1357	12.3952
Others	0.0443	0.0756	0.0872	0.0949	0.0197	0.0172	0.0768	0.4157
Total	25.6173	22.7894	29.1761	40.269	40.1102	36.8281	66.6772	261.4673
Gross Imports of Wood (Predominantly Paper)	4.6100	6.8448	4.8599	10.8708	12.8187	8.7281	7.1058	55.8381
Net Exports	21.0073	15.9446	24.3162	29.3982	27.2915	28.1000	59.5714	205.6292

(Source: Annual Reports Forestry Dept., Ghana) opportunities for gainful employment. These persons may include unskilled, semi-skilled as well as skilled persons who may be first employed to carry out simple operations and then trained on the job to acquire skills requiring various degrees of sophistication. Skills obtained as a result of those needed by Forest management in rural areas include tree spotters, forest guards,silvicultural labourers, power saw operators, timber truck drivers, sawmill technicians, graders, saw doctors, kiln operators, office clerks, carpenters, masons, etc.

Most of the 25,340-47,540 persons employed on the production of lumber, veneer and plywood annually from 1966 to 1972 (Table 32) and some 2220-5260 employed annually by Forestry department during the same period (Table 33) are permanent rural dwellers. One very significant feature of forestry and forest products industries is the removal of disguised unemployment in rural areas of Ghana. Thousands of rural dwellers engaged on agriculture and the cottage industries have idle periods of up to 200 days in the year and many such persons can be absorbed by forestry with practically no detrimental effect on their former employment. In effect forestry and forestproducts industries reduce unemployment or underemployment and therefore increase productivity of rural dwellers. An important consequence of this is that rural dwellers can rely on a regular source of income, instead of the periodic source of income provided by cocoa which maintains rural dwellers on a comfortable standard of living between November and May, and makes them heavily indebted to money lenders from about June to October every year. Forestry and Forest products industries are characterised by:

(iii) Capital accumulation in the form of annual increments of managed natural forests as well as plantations. Under proper management capital accumulation ensures regular employment in forest products industries. The regular maintenance of the forests also provides a permanent source of employment to rural dwellers. In addition to the above the strong forward linkages of forestry and forest products industries have produced very important social effects extending beyond the rural areas:

(iv) Road construction, which inevitably precedes felling and extraction in remote areas of high forest, opens up the country and encourages foodcrop and subsequently cocoa farming in unreserved forests.

Availability of food and cocoa leads to permanent settlements, and regular communications with the cities. The benefits in the form of income, housing, trade, etc,are enormous.

(v) Forestry and forest products industries provide improved housing for employees, and they bring in amenities such as good water supplies, electricity, hospitals, schools, post offices, banks, police, technical education, etc, normally not available in some rural communities.

(vi) In addition they also encourage flourishing businesses in food, clothing, drinks, oil, etc.

(vii) They also help to develop and maintain industries based mainly on wood such as furniture industries, boat building, manufacture of boxes, cabinets, toys, fencing materials, tool handles, brush handles, shoe soles, charcoal burning and firewood retail. The last two items are perhaps the most important adjuncts to sawmill, veneer and plywood mills in rural areas of Ghana.

(viii) They also lead to a concentration of gainfully employed and more comfortable rural dwellers who can afford to pay the regular annual levy of ₵2.00 per head to Local Councils. The revenue so collected enables the Councils to run schools and maintain health centres and other essential social services in rural areas.

Where the industries are established in urban and city areas several of the benefits outlined such as capital inflow, employment, improved housing, small business investments, also flow on to the city and urban dwellers.

4.2 BENEFITS TO GHANA

The management of forests and the establishment of forest industries in rural, urban and city areas in the GTHF have very important economic and social benefits including the following:

(a) Foreign exchange earnings by the Ghana Government: Considerable amount of foreign exchange (Table 32) is earned by the Ghana Government to help pay for external debts owed by the government. A substantial amount of capital in the form of sawmills, plywood and veneer plants and equipment representing foreign investments in Ghana, also add to the foreign exchange earnings by Ghana. Both these earnings represent autonomous injections of spending to Ghanaians (values of investments and exports) which should result in the increase in real Gross National Product. The multiplier effects of these injections may not be spectacular since Ghanaians may spend up to two-thirds of the additional income on foreign goods, but they should be large enough to represent real increases im GNP.

(b) Employment: The employment of a large number of persons already referred to, is an important step towards the achievement of full employment in future.

(c) Increases in Consumption and Investment: Forestry and forest product industries contribute to increases in consumption and investment by the employees, timber producers and processors. Some of the consumption flows on to suppliers of other goods who can make further investments and ensure further increases in future consumption. The actual multipher effects of employment, consumption and investment are unknown, but they must be reasonably large.

The consumption of locally produced lumber, plywood, and veneer, especially for dwelling constructions, represents a important decrease in the drain on foreign exchange and therefore a significant effort towards the maintenance of a stable Ghanaian currency.

(d) Increase in tax revenue: The Ghana Government collects taxes on profits from log producers, saw-mill, veneer and plywood mill owners, and retailers of forest products. These taxes must have a substantial effect on the fiscal and monetary policies of the Government.

In addition, employees pay payroll taxes collected at source and paid into the social security fund by the Ghana Government.

(e) Amortization of costs of services: Forestry and forest products industries lead to speedy amortization of the cost of roads, ships, water supplies, electricity, aeroplanes, since these services are very well used by the industries.

(f) Social benefits: In addition to the above there are a host of benefits to Ghanaians in the form of:

(i) Reduction of population pressure on cities;

(ii) Certainty of sustained yield from cocoa farms in the form of increases in cocoa farm areas in exploited unreserved forests, and maintenance of the suitable climatic conditions for the growth of cocoa;

(iii) Sanctuary for the breeding of wildlife,

(iv) Consumer surplus and producer surplus since the forests are communally owned;

(v) Beautification of the countryside.

4.3 BENEFITS TO COUNTRIES OVERSEAS

Overseas countries such as Italy, France, Western Germany, Portugal, United Kingdom, Belgium and Denmark that import very substantial quantities of sawlogs as well as sawn timber from Ghana, and importing countries in West Africa, gain many benefits from tropical hardwoods. Among the important benefits are:

(a) Satisfaction of demands of increasing affluence for highly decorative, utility, and excellent structural timbers.

(b) Substantial increase in employment which is a further step towards the attainment of full employment status.

(c) Substantial increase in foreign exchange earnings from overseas investments in tropical timbers.

(d) Large increases in foreign exchange from the export of processed wood to other countries.

The following quotation from FAO (1967) underscores this: "The striking feature of trade in tropical hardwood, plywood and veneer is that about half of the worlds exports comes from countries outside the tropics which manufacture these products from imported tropical hardwood logs". The amounts of such sawlog exports from West Africa have already been given (Table 20).

PART IV

CHAPTER 5

THE EVALUATION OF SILVICULTURAL APPROACH TO FORESTRY IN THE GTHF

This chapter emphasizes the bearing the various factors referred to in earlier chapters (Chaps. 2-4) may have on silvicultural management of the GTHF. It also suggests how those factors have been or can be effectively synchronized with the silvicultural methods to achieve the aims of management.

Silviculture is undeniably the direct guiding principle applied to all the managed forests of the world. However, it is only a means to an end. It cannot be arbitrarily chosen, but it should be the logical result from the interactions of sociological, economic, biological and environmental factors which are to be considered in this chapter.

5.1 SOCIOLOGICAL FACTORS AFFECTING MANAGEMENT OF THE GTHF

The ultimate objective of management of the GTHF is the welfare of Ghanaians in particular and the world in general. Sociological factors affecting human welfare include, of course, economic and environmental factors both of which will be dealt with separately and do not therefore appear in this sub-section which is devoted to certain peculiarities of the Ghanaian society. These concern Forest Law, Ownership of Forest reserves and the effects of Shifting cultivation and Cocoa farming on the maintenance of permanent forest reserves (Sub-section 22,23).

5.1.1 Forest Law and Forest Management in the GTHF

The problems affecting the implementation of the Forest Law (section 2) appear discouraging to the future management of the permanent forest reserves in the GTHF. However, the recognition by the Ghana Government of some of the important reasons for maintaining a permanent forest estate in the GTHF (Sub-section 2.5.2) does indicate that the future of forestry can be bright. An effective forest law is therefore imminent and the following recommendations are made:

(i) The Ghana Government should set up a committee made up of the Attorney General's Department, Lands Department, the Political Administrations within the GTHF, the House of Chiefs, Forestry Department, etc, to make recommendations to Government as to the precise laws required for the effective implementation of the Forest Policy.

(ii) The recommendations, if approved by Government, should be enacted as a body of Forest Laws in a single volume, serially numbered with additional numbers for amendments, etc.

(iii) The laws should be circulated to Forestry, the law courts, the House of Chiefs, etc.

(iv) The Committee should meet at least once in 5 years to hear progress reports by the Forestry Department and perhaps the Law Courts, on the operation of the Forest Laws so that further recommendations, as appropriate, can be made and a new volume issued.

(v) The Forestry Department should in addition be able to present its case to the Ghanaian Public in the form of regular broadcasts, meetings, publications, etc, all geared to meet the needs of all sections and shades of opinions of the general public.

5.1.2 Ownership of Forest Lands and the Management of the GTHF

The importance attached to the delicate question of ownership has already been expressed (sub-section 2.2). There will be no need for expropriation or outright purchase of any forest lands reserved by Government. The Government does not need to go beyond the present conditions under which the Forest Lands are held in trust for the owners. However, the present method of forest land revenue to owners need to be changed. With proper safeguards land owners could be paid salaries relating to their average annual forest revenues and perhaps their status. Such salaries could be budgeted for by the Local Administrations concerned and regularly paid by them. All revenues from forest reserves would then be paid into the forest fund or the appropriate government account. This will relieve the Forestry Department of unnecessary embarrassment, and the Lands Department of additional burden.

5.1.3 Shifting Cultivation and Cocoa Farming and their Effects on Management of the GTHF

It has been said that the success of forest management may be measured not only in terms of good forestry and good economics but also on good politics (Zivnuska, 1966). A combination of all three appears to have been successfully applied in the Agri-silvicultural method (Taungya) of plantation establishment (sub-section 3.3.3). Forest trees are well spaced over the planted area to accommodate food crop cultivation for a period of 3 years during which the farmer maintains the area. He also takes part in the clearing, burning, collection of debris prior to cultivation. He can increase his farm area, and also ensure annual cropping, by taking new areas for farming every year so long as the plantation programme continues. The Forester deliberately encourages shifting cultivation and gains the co-operation of the farmer. Nutrient depletion by food crops may mean longer rotations, but the low cost of establishment may still help to make the plantation project economic.

This Forester - Farmer co-operation needs to be encouraged so long as it is clearly understood by all that it will be confined to certain patches of poor forest in the GTHF, and also that cocoa farming will not be tolerated. It is considered that a further extension of cocoa beyond areas outside forest reserves threatens the very existence of the GTHF and the future of cocoa itself (sub-section 2.5.2). Maintenance of the current cocoa production level (Table 16) must be achieved by rehabilitation of thousands of hectares of abandoned cocoa farms. Ghana has sufficient experience to be able to maintain the present level of really good quality cocoa production from those areas already planted up with cocoa. We may not be able to retain the position of being the largest producer of cocoa but we have the experience to be able to tell the world that we produce the best quality cocoa. We cannot afford to extend cocoa into forest reserves as Nigeria has attempted to do (Adeyoju, 1974).

The ultimate success of the patches of man-made forests will, however, depend on the continuation of the excellent co-operation between the Forestry Department and the FPRI so that the right type of species may be planted to supply, in the long term future, the required quality of timber in sufficient quantities to supplement timber production from the natural forests.

5.2 ECONOMIC FACTORS AND FOREST MANAGEMENT IN THE GTHF

Economic factors constitute the tangible criteria for human welfare (Worrell, 1970). In Forestry some of the most important economic factors are finance (Costs and returns), marketable products, market situation, supply and demand all of which have been discussed in the sub-sections that follow:

5.2.1 Forest Finance

The financial aspects of Forestry affect cost and returns which also affect the rotation length or the felling cycle (section 5.3).

Financial needs of forestry for costs of projects are such that they must be guaranteed over a long period commensurate with the long term nature of Forestry. Annual fiscal policies of modern governments create problems for Forestry projects. The Ghana Government, however, has long recognised the importance of Forest management in the GTHF and has made special arrangements in the form of a Forest Fund to ensure continuity of Forestry projects irrespective of when annual budgets are brought down. This is a good policy that deserves to be pursued to achieve the aims of management.

Financial returns far outweigh the costs of management (Tables 32-34). However, the fixed royalties paid for trees (Sub-section 2.5.4.2) do not appear to be satisfactory.

It has been argued that the timber producer or sawmiller should pay royalty on the residnal value of the net volume as it stands in the forest, because this is the volume that is marketed

(Ken Phyllis, 1971). In Ghana this would mean payment of royalty on the value of approximately 35% of the volume of the tree less felling and extraction costs, transportation costs, etc. (20% of the tree is left in the forest and 57% of what is extracted becomes sawmill waste). This is similar to charging the royalty on the profit (MacGregor, 1961). Available information on the costs and returns of the operations of timber firms is scanty, and until this is carefully studied the royalty rates should remain the same as they are. However, it is hoped that this study can be initiated as soon as practicable.

5.2.2 Marketable Products

The Lumber, veneer and plywood are required as general utility, structural and decorative timber. The specific uses of the lumber, veneer and plywood have been listed (Table 7). There are some 320 species still not well known on the timber market. Since wood species have been found to be interchangeable (Lorensen, 1973), it is hoped that some of these species can be used as substitites if the FPRI can establish their specific qualities for any of the three uses, especially for decorative and structural purposes, for which tropical hardwoods have been found to be generally superior to temperate species. The research work by the FPRI in this direction deserves to be encouraged as it should be able to produce quick results.

5.2.3 The Future Market Situation

This sub-section will be divided into two, namely, future markets and future supply and demand.

5.2.3.1 Future Markets

Assuming that past trends continue, then there is no doubt that the overseas market will continue to be important. However, the sellers need to learn more about the market conditions and it is recommended that the GTMB, FPRI, the Ghana Timber Association (GTA) and the Forestry Department co-operate to set up a market intelligence section to supply information such as the following to all concerned with Ghanaian Timber:

(i) Tropical hardwood market situation in different parts of the world.

(ii) Current economic conditions of the major importing countries likely to affect the trade in tropical hardwoods.

(iii) Technological developments likely to affect the trade in tropical hardwoods.

(iv) Tropical hardwood resources of the world and investments (old and new) in tropical hardwood industries in different countries.

(v) Alternative markets for Ghana timber.

(vi) Levels of stockpiles for lumber, veneer and plywood in the importing countries.

(vii) Plants and equipment for forest industries in different parts of the world, etc.

In addition to the market intelligence research it will be necessary for all countries in West African region (Exporting and Importing countries) to form a West African Timber Resources

Association (WATRA) to meet at least once in a year to exchange ideas on timber and to publish papers.

5.2.3.2 Future Supply and Demand

If past trends continue then it is hoped that the actual future timber requirements for Ghana will be as near as possible to the figures in the forecasts. However, the following factors which are likely to create modifications in the proportions of supply and not the total sawlog production, should be watched carefully:

(i) Ghana Governments Policy of Participation.

(ii) Steady growth in timber consumption by Ghanaians.

(iii) Sawlog exports,

(iv) Sawmill waste.

Ghana Government's Participation Policy

As a result of its participation policy the Ghana Government has since 1972 entered into equity partnerships with Foreign owners of forest products industries (sawmills, veneer and plywood mills). This could adversely affect trade and investments, especially from the United Kingdom, which has perhaps been more affected than any other European countries. However, this policy is an inevitable outcome of unfair business arrangements in the past, and it is hoped that it will be accepted in good faith. There is, however, the possibility that the United Kingdom may divert future investments in forest products industries for tropical hardwoods to the Central and South Americas which between them have over 150,000 million M^3 of merchantable timber as against

Africas 30,000 million M^3 (Lorensen, 1973). If this happens it should not be too difficult, through market intelligence, to find new buyers overseas or to divert a percentage of good quality material to the local Ghanaian market. Ghana and West Africa in general are so strategically placed that there will always be markets in timber products. Current investments in the industries affected by the participation policy need to be carefully watched and increased where necessary to ensure further economies of scale.

Growth in the Consumption of Forest Products by Ghana

As it has already been explained (Sub-section 2.5.4.4) consumption of timber products, especially lumber, by Ghanaians is low.

Further investments in sawmills are low and if past trends continue it is very likely that actual production of sawn timber will decline and with this will be a rise in the amount of sawmill waste as the forecasts correctly indicate (Table 27). If the export market for lumber continues to remain important (as it is likely to do) and the sawn timber exports rise, then the consumption of sawn timber in Ghana will remain low, and infact decline markedly. If there is to be an increase in the sawn timber available to the Ghanaian market, the behaviour of the export market for sawn timber will need to be carefully watched along with possible further investments in sawn timber, and perhaps increases in efficiency of sawing.

Unlike sawn timber the consumption of veneer and plywood, though at a very low level, appears to be increasing, and this upward trend in consumption has been reflected by the forecasts (Table 27). It is reasonable to state that the future consumption levels will be possible because of investments recently made in veneer and plywood mills.

The forecasts have not made any allowance for the supply of timber from the man-made forests because it is considered that these forests will not yield any timber of importance up to year 2000.

Sawlog Exports

Some of the factors that have discouraged investments in forest products industries in the West African region have been attributed to lack of managerial ability, political instability, lack of trained manpower and lack of finance. Comparisons of production and consumption of timber in Ghana under three types of Government from 1966 to 1968, 1969 to 1970 and 1971 to 1972 (Table 18) shows that changes in Government do not appear to have any significant effects on the timber industry, and the exports to Western Europe have continued to improve irrespective of what political changes take place.

Exports of lumber, veneer and plywood from Ghana for long periods should be enough to dispel any doubts about managerial ability and trained manpower. In fairness to the trade it is considered necessary for Ghana to enter into trade agreements with the sawlog importing countries such as Western Germany, France, Italy, etc, to ensure the establishment of lumber, veneer, and plywood mills in Ghana and to gradually phase out the supply of sawlogs to those countries.

Such industries should cope with the lumber, veneer and plywood requirements now catered for by sawlog exports to the countries concerned. The point of crucial importance is the necessity for Ghana Government to make financial arrangements in equity partnership with the countries that may agree to the establishment of the mills.

If such an action is not taken the continued investments in mills overseas will ensure further economies of scale in those industries and this will lead to increases in sawlog exports as indicated by the forecasts. Such a situation will be detrimental to the retail trade in Ghana.

No increases in sawlog production beyond those in the forecasts should be anticipated, as this could be harmful to the stability of the forests. Export of sawlogs need to be stopped as soon as practicable with the co-operation of the buying countries.

5.2.3.2.4 <u>Sawmill Waste</u>

Allowance has been made in the forecasts of future production, exports and local consumption (Table 27) for sawmill wastes varying from 56% to 62% of the sawlogs reaching the sawmills. The reasons for this have been given in sub-section 5.2.3 above. However, such a level of waste cannot be endured indefinitaly, and it is considered necessary for Ghana to finance research by the Kuman University of Science and Technology or some other agency, with the aim of finding means of reducing losses in wood conversion.

Savings made in conversion can be absorbed by the Ghanaian retail market.

5.3 ENVIRONMENTAL FACTORS AFFECTING THE MANAGEMENT OF THE GTHF

Soil erosion, water turbidity, forest clearing and general environmental pollution adversely affect the biological stability of the GTHF as already explained (sub-section 2.4.5.8). The nature of logging operations (sub-section 2.5.3) is such that a certain amount of temporary damage to the environment is unavoidable, but the damage can be minimized by improving logging standards and shortening the period over which logging takes place.

This could reduce the extent of erosion and ensure the early return of wildlife.

Logging hygience will be necessary to reduce the amount of environmental pollution. To ensure that the general environment of the GTHF is not seriously damaged, it will be necessary to adopt the following guidelines:

(i) The location of logging roads and loading stations should continue to be the responsibility of the District Forest Officer and the concessionaire working together; and the final layout of the road should be approved by the District Officer only after a ground reconnaissance.

(ii) Roads should be well cambered and consolidated to allow running water to move freely but as such a velocity as to cause very little erosion of surface soil.

(iii) Roads should avoid steep slopes and steep hill-sides where practicable, and they should have a normal longitudinal gradient of 1 in 40, and and a ruling gradient of not more than 1 in 10 in difficult areas.

(iv) Culverts and bridges, with allowance made for safety margins, should be constructed over streams that must be crossed.

(v) Side drains should always be kept clear and clean, and pot-holes should be filled and consolidated as soon as they appear.

(vi) Waterlogged areas should be avoided as much as possible in the location of logging tracks.

(vii) Where directional felling is practicable trees should be felled into areas where the least damage to the residual stand can result.

(viii) Trees, saplings and poles bent as a result of felling should be released either by removing entangled climbers or by cutting them back.

(ix) Fellings should be restricted to trees marked for felling and none other. Regular inspections of felling areas by the District Staff should be encouraged to continue.

(x) The tops of trees falling into streams should be removed to clear the stream channel, where such an action is practicable.

(xi) Concessionaires should not leave compartments if felling is not completed.

(xii) The logging staff should not be allowed to use snares, fishing nets. Guns should only be used in self defence.

(xiii) Fossil fuels, empty cans, discarded parts of machines, waste paper and plastics, should be carried back to the mills and disposed of at the appropriate places.

(xiv) The District Officer should have the right to suspend logging operations of concessionaires who persistently fail to observe the necessary environmental constraints.

In plantation areas the following precautions should be taken in addition to the those already outlined:

(i) The area of a continuously cleared belt of man-made forest should not exceed 1–3 square miles depending on how poor the forest is and the number of rivers present and nature of the terrain.

(ii) Watersheds and large rivers should be left in the natural forest where they occur in plantation areas.

(iii) The interval between felling, burning and planting should be reduced to the minimum practicable.

(iv) Seed imports should be avoided if possible, otherwise strict quarantine regulations should be observed.

The observance of the above listed points will not only ensure the achievement of the necessary environmental hygience for the maintenance of stability, but it will also leave the forests in the suitable condition for people who may in future visit them for various reasons such as rejuvenation, spartanism, primevalism, achievement, and escapism (Hendee, 1969).

5.4 ECOLOGICAL AND BIOLOGICAL FACTORS AFFECTING MANAGEMENT OF THE GTHF

In general the GTHF are climatic climax forests in dynamic equilibrium with the climate, soil and other biotic factors of the environment.

They undergo very slow but steady change, recycle themselves through death, putrefaction, nutrient uptake, regeneration of species that attain different sizes, storeys, and have different light demanding characteristics at different ages. Death may result naturally from disease, senescence, and mechanical effects in patches to ensure sufficient openings that make the recycling process possible.

Elaborate information has been given on species environment relationships, competitive ability, biomass limitation, growth rates of selected species and the significant effects of canopy cover (Chapter 2) and these need not be repeated.

A point of singular importance that has also been stressed several times in earlier sections is the need to maintain the GTHF in a natural and relatively stable condition, that is, to maintain the continued operation, in perpetuity, of the ecological and biological processes in accordance with the objectives of management.

The problem then is to determine the silvicultural management that is biologically, ecologically, sociologically and environmentally sound (Florence, 1970). Cyclical removal of selected trees of MEG has been found to be basically sound as it can create conditions similar to those of natural periodic shocks caused by thunderstorms and diseases. The trees felled during these cyclical operations have satisfactorily maintained regular operations in sawmills, plywood and veneer mills in Ghana and Western Europe, and have also maintained in business many concessionaires who concentrate mainly on logging of tropical hardwoods. All the above have taken place despite the low yield from forest reserves (Sub-section 2.4.5.4). With dwindling reserves of merchantable economic trees from areas outside forest reserves, these forest reserves are going to be the main suppliers of sawlogs in future. It is considered that the present low yield can conveniently be doubled to meet the demand as indicated by the forecasts provided the list of economic species is extended, and provided the felled areas are given a sufficient period of rest for recuperation.

Such a conservative management of the mixed species forests is not new. In sub-tropical Queensland mixed species natural Eucalypt forests have been conservatively managed with a minimum disturbance at each logging, and with the maintenance of an irregular stand structure (Florence, 1970). However, experience in

Ghana has shown that the thinnings that precede the selective fellings, though fundamentally sound, cannot be expected to achieve results better or even similar to those naturally achieved without human assistance (Section 3). In addition these thinnings have introduced a further environmental problem in the form of sodium arsenite. The biological effects of arsenite are detrimental to the stability of the GTHF, not to mention the additional poisons that arsenite can introduce into water supply in areas within the GTHF.

The following recommendations are therefore made for the management of the GTHF:

(i) That cyclical fellings under the polycyclic system be continued but that the times of passage (TOP) used in yield calculation be extended. The TOP of 70 years (minimum) for Class I trees between 5-7ft. and 9-11ft. girth classes, and 80 years (minimum) for Class II trees between 3-5ft. and 7-9ft. girth classes, is recommended. These TOP will better take into consideration the variations in growth rates of economic species.

(ii) That the yield calculation be based on area, TOP, MEG, density of stocking, and an economic index affecting the market situation at the time of felling. The economic index may be called the Marginal Propensity to Produce or Export (MPP or MPX). If the calculated yield based on the first four variables referred to above is removed from say 4 sq. miles of forest selectively felled per annum, and market intelligence reports indicate that where prices in real terms were ¢100 during the previous year, and are currently ¢120 for the same product (say sawn timber for the major export species), then MPX* = 9/11 for lower current prices and 13/11 for higher current prices. The actual area to be selectively felled annually then becomes 3.27 sq. miles when market conditions are unfavourable for production and 4.73 sq. miles under favourable market conditions. This flexibility will be necessary to maintain prices at reasonable levels during trade cycles without unnecessarily upsetting the manpower engaged on forestry operations.

(iii) That the minimum merchantable girth limits be strictly maintained at their present levels of 11ft. for all economic classes except for _Lovoa trichilioides_, _Terminalia ivorensis_, _Guarea cedrata_ and classes Ic and IIb which may all be felled at 7ft. These latter species reach merchantable sizes at lower girths. The establishment of plantations in patches of natural forests (Sub-section 5.1.3) should continue as these plantations are likely to become an important supplement in the long term because of their advantages in species concentration, bolewood volume productio

---

* $$\frac{9}{11} = 1 - \frac{20}{\frac{1}{2}(100 + 120)}$$

ease of supervision, roading, harvesting and growing stock control (Florence, 1973).

(iv) That a large percentage of the GTHF irrespective of floristic association and productivity in terms of economic classes, but strategically placed to maintain the required protective function, be dedicated as a permanent natural tropical high forest. Such a dedication should be considered as sacrosanct even though the cyclical selective fellings will continue where necessary.

(v) That encouragement be given to logging and processing methods that will lead to a reduction in timber damage by insects.

PART V

CHAPTER 6

SUMMARY OF RECOMMENDATIONS

This section is intended to summarise the various recommendations made to meet the ecological, biological, sociological and environmental needs of the GTHF.

Briefly these recommendations are as follows:

(i) The dedication of a large percentage of the GTHF to permanent natural stable forest to supply direct short term as well as long term benefits in the form of timber, and materials for cottage industries, as well as indirect benefits in the form of maintenance of equable climate for the growth of agricultural crops and for the protection of soil and water.

(ii) The up-dating of forest laws to deal effectively with infringements under rapidly changing socio-economic conditions of a developing country such as Ghana. This is to be accompanied by public education on forestry in the form of regular broadcasts, meetings, publications aimed at the cross-section of the general public in Ghana.

(iii) The streamlining of disbursements of forest revenues to land owners by arrangements which will ensure regular payments of salaries, commensurate with annual revenue disbursements, through the local political administration.

(iv) The continuance of the Forester-Farmer co-operation in the establishment of man-made forests which should be restricted to certain selected areas in the GTHF. The strict adherence, in such areas, to the conditions that no permanent cocoa crop is to be tolerated.

(v) The operation of the Forest Fund should continue and it should allow sufficient flexibility to enable long term projects to be undertaken irrespective of the times of Government budgets.

(vi) The initiation of studies on the costs and returns of timber operations with the view to possible revision of stumpage rates.

(vii) Encouragement of research by the FPRI into the qualities of lesser known species and their subsequent promotion as substitutes for decorative, general utility and structural timber.

(viii) The setting up of a Market Intelligence department to provide the timber industry with all facts pertaining to the market conditions and acquisition of plants and equipment and investment opportunities.

(ix) The continuance and further encouragement of Ghanaian participation in the Forest products industries, and the conclusion of agreements by Ghana and sawlog importing countries for the establishment of sawmills and especially veneer and plywood mills in Ghana on equity participation basis.

(x) Encouragement of research by FPRI or Kumasi University of Science and Technology aimed at reducing sawmill waste.

(xi) The enforcement of logging hygiene to reduce environmental pollution.

(xii) The continuance of cyclical fellings under the polycyclic system in permanent natural forests but with times of passage between size classes increased for yield calculation, and with an economic index built into the effective area of the annual coupe to ensure flexibility.

(xiii) The strict adherence to the MEG of 11ft. and 7ft. depending on the biological behaviour of the economic species.

(xiv) The adoption of logging and processing methods that will reduce waste resulting from insect attack.

BIBLIOGRAPHY

Adekunle, A.O. 1971. The non-timber forest resources of the high forest areas of Nigeria. Nigerian Jour. For. Vol. 1, No. 1.

Adeyoju, S.K. 1974. Forest Resources of Nigeria. Comm. For. Rev. Vol. 53(2) No. 156.

Ahn, P.M. 1959. Soil/Vegetation relationships in the Western Forest Areas of Ghana.

Anon, 1966. Animaux sauvages du Togo et de L'Afrique Occidentale.

_____ 1970. The Forest Resource and its use. Paper presented to Forestry refresher course, Victoria Sch. of For. Creswick, May 17-28.

Asmah, J. 1970. Development of Grading rules for timber of mixed tropical forests. Management Seminar for the GTHF, Ghana.

Ashley, A.W. 1956. Lands - An FAO Land Tenure Study, Rome.

Anin-Bonsu, B. 1970. What do we do with overmature trees in Ghana? Management seminar for the GTHF, Ghana.

Baade, H.W. African Law.

Baidoo, J.F. 1970. Yield Regulation in the High Forests of Ghana. Management Seminar - the GTHF.

__________ 1970. The Selection System as practised in Ghana. Comm. For. Rev. Vol. 49(2), No. 140, June, 1970.

Beazley, R. (n.d.). Planning and developmental requirements in the Forest Land Sector of less developed countries.

Bendt, H.W. and Swank, G.W. 1970. Forest Land-Use and Streamflow in Central Oregon. USDA For. Serv. Res. Paper PNW-93.

Birmingham, Newstadt and Omaboe, 1967. A study of contemporary Ghana. Vol. 2.

Bletchley, J.D. 1961. A review of factors affecting abrosia beetle attack in trees and felled logs. Emp. For. Rev. Vo. 40 (13-18).

Cansdale, C.S. 1960. Animals of West Africa. Longmans Lond.

Carron, L.T. 1974. Lecture notes for M.Sc. Course Work.

Casely-Hayford, J.E. 1971. The truth about the West African Land question.

Clifford, J. and Gavin Osmond, 1971. World Development Handbook. Charles Knight & Co., London.

Connaughton, C.A. 1970. The revolt against clear-cutting. J. For. 68:264-265.

Cromer, D.A.N. 1967. Forest Management. World Symposium on Man-Made Forests and their Industrial importance. Canberra, 14-25 April, 1967.

Danso, L.K. 1966. Enrichment and Management of the GTHF (unpublished).

Darlington, F. 1968. Impacts of man on the Biosphere. Proceed. of Inter Govt. Conf. of Experts on Sc. Basis for rational use and Cons. of the resources of the Biosphere. Paris, 4-13 Sept. 1968.

Dawkins, H.C. 1958a. The management of the natural tropical high forests with special reference to Uganda. Oxford For. Inst. Paper 34.

Dawkins, H.C. 1961. New Methods of Improving Stand Composition in the tropical high forests. Caribbean Forester, Vol.22, Nos. 1 + 2: 12-20.

__________ 1963. Crown diameters. Their relations to bole diameter in tropical forest trees. Comm. For. Rev. Vol. 42 : 318-333.

__________ 1965. Problems of natural regeneration, plantations and research. Report to For. Div. of Mins. of Natural Resources, Sierra Leone.

Dorner, P. 1972. Land Reform and Economic Development. Frank Cass & Co., London.

Dowdle, B. 1962. Investment Theory and Forest Management Planning. Yale Univ. Sch. of For. Bull. 67.

Elias, T.O. 1971. Nigerian Land Law, London.

Eyre, S.R. 1968. Vegetation and Soils, a world picture.

Duffield and Dawes, K.P. Society of

FAO, 1966-1967. Annual Forest Products Market Review, Geneva.

____ 1967-1968. Annual Forest Products Market Review, Geneva.

____ 1968-1969. " " " " " "

____ 1969-1970. " " " " " "

____ 1970-1971. " " " " " "

____ 1971-1972. " " " " " "

____ 1972-1973. " " " " " "

____ 1973-1974. " " " " " "

____ 1967. World Trends and Prospects. FAO Basic Study No. 16 Published in Wood.

Ferguson, I.S. 1974. Lecture Notes for M.Sc. Course Work.

__________ 1973. Land-Use Planning, Analysis for Action. ANU Paper.

__________ 1974. Future Forest Policy. An Analytical Review. ANU Paper.

Florence, R.G. 1974. Lecture Notes for M.Sc. Course Work.

__________ 1967. Factors that may have a bearing upon the decline of productivity under forest monoculture. Aust. For. 31 : 50-71.

__________ 1970. Conservative Silvicultural Practice in Irregular blackbutt forest. Comm. For. Rev. Vol 49(1), No. 139

__________ 1972. Resource Use, Biological and Environmental Planning for Eucalypt Forest Management. 26th General Conf. Appita, Hobart, Feb. 1972.

__________ 1973. Silvicultural Practice in Eastern Hardwood Forests. Jour. For. Vol. 71, No. 8, Aug. 1973.

FPRI, 1967. Annual Report of FPRI, Ghana.

Francois, J.H. 1972. Annual Reports of the Forestry Division, Mins. of For. Ghana, 1966-1971.

__________ 1974. Annual Reports of the Forestry Division, Mins. of For. Ghana, 1972.

Freese, F. 1962. Elementary Forest Sampling. USDA For. Serv. Pub.

Ghana Govt., 1969. Economic Survey Report Ghana Publishing Comp.

__________ 1974. Report of the Salary Review Committee. Ghana Publ. Corp.

Gilmour, D.A. 1971. The effects of logging on streamflow and sedimentation in a North Queensland rainforest catchment. Comm. For. Rev. 50 : 39-48.

Hendee, J.C., Catton, W.R. Jnr., Marlow, L.D. and Brockman, C.F. 1969. Wilderness users in the Pacific North West, their characteristics, values, and management preferences. USDA For. Serv. Res. Paper PNW-61.

Hill, L. Land and People, Leonard Hill Books.

Irvine, F.R. 1961. Woody Plants of Ghana. Oxford University Press.

Jack, W.H. 1958b. Low percentage enumeration for Management in the Ghana Tropical High Forests. Proceed. of West African For. Conf. at Pointe Noire, 89-103.

__________ 1961. The Spatial distribution of Tree Species in the Tropical High Forest. Emp. For. Res. Vol. 40 £ 234-240.

Johnson, D.R. 1972. Formulation and Implementation of Forest Policy. For. Commission Res. Development Paper., July 1972.

Keay, R.W.J. 1961. Increment in the Okomu Forest Reserve, Benin. Proceed of 13th Congress of IUFRO.

Kovda, Prof. V. 1968. Contemprary Scientific concepts relating to the biosphere. Proceed. of Inter Govt. Conf. of Experts on Sc. Basis for rational use and Cons. of the resources of the Biosphere. Paris, 4-13 Sept. 1968.

Lancaster, P.C. 1961. Experiments with natural regeneration in Omo F.R. Nigerian Forestry Information Bull. No. 13.

Lane, D.A. 1958. Notes on Silvicultural Methods in use in Ghana. Proceedings of the 2nd Inter-African Forestry Conference at Pointe Noire, 236-237.

Leaf, A.L. and Leonard, R.E. Measurement of Environmental Characteristics of a Forest Stand. XIV IUFRO-KONGRESS Sec. 21 : 281-297.

Leslie, A.J. 1971. Economic Problems in Tropical Forestry, FAO, Rome.

Lorensen, C.C. 1973. Future sources of hardwood supplies. Comm. For. Rev. Vol. 52(4) No. 154, Dec. 1973.

Mervart, J. 1972. Growth and mortality rates in the natural tropical high forests of Western Nigeria. Nigerian For. Information Bull. (New Series) 22. Federal Dept. of For., Ibadan.

Mooney, J.W.C. 1958. Selection Management in the tropical moist semi-deciduous forests of Ghana. Proceedings of the 2nd Inter-African For. Conference at Pointe Noire, 147-157.

__________ 1961. Site indices in natural and selection forest. Proceedings of the XIII IUFRO Congress Paper No. 23/3-S/1.

__________ 1962. The tropical shelterwood system in the high forest of Ghana. Proceedings of the 8th British Comm. For. Conf., 205-208.

MacGregor, J.J. 1960. Economics and the use of Land for Forestry. UNASYLVA, Vol.14, No.2.

__________ 1961. A possible mechanism for determining timber fees and royalties. Emp. For. Rev. Vol. 40 : 154-161.

Mohr, E.C.J. and Van Baren, 1959. Tropical Soils.

Nelson, A.W. 1971. An environmental approach to silviculture. Jour. For. 1971 : 322-334.

Nye, P.H. 1954. Some soil formaing processes in the humid tropics. Jour. West. Afric. Sc. 7-21.

Ovington, J.D. 1965. Organic production, turnover and mineral cycling in woodland. Biol. Rev. 40 : 295-336.

Owusu, J.G.K. 1972. Forest Laws of Ghana and Court Procedure.

Parkes, E.D. 1974. Lecture Notes for M.Sc. Course Work.

Phillis, K. 1971. Management Inventory of Irregular Broadleaved Forests of Australia. Ph.D. Thesis, A.N.U.

Rattray, Capt. R.S. 1969 (Revised). Ashanti.

Reilly, J.J. 1972. The implications of increased demand for Forest Products to rural areas in Australia. 44th ANZAAS Congress, Sydney.

Rendle, B.J. 1969. World Timbers - 1 - Europe and Africa.

Rosevear, D.R. 1951. Nigerian Mammals.

Samuelson, Hancock & Wallace, 1970. Economics. Aust. Edition.

Simpson, G.G. 1945. The Princples of Classification, and classification of mammals. Bull. of American Museum of Nat. History. Vol. 85.

Stevens, P.R. 1971. Forest Ecosystems with reference to intensive Forestry. Forest tree Nutrition Conference, 6-9 Sept. 1971.

Taylor, C.J. 1952. Vegetation zones of the Gold Coast. Ghana Govt. Printing Press.

__________ 1954. Research Methods and records connected with the Tropical Shelterwood system in the Gold Coast. Emp. For. Rev. 33 : 150-157.

Urquhart, D.H. 1955. Cocoa. Longmans, London.

Watt, G.R. 1973. The planning and evaluation of forestry projects. C.F.I. Paper 45.

Westoby, J.C. 1964. Forest Industries on the attack on economic underdevelopment. UNASYLVA 16(4) : 168-201.

Willis, W.E. 1968. Timber from the Forest to the Consumer.

Wolman, Dr Abel 1968. Problems of deterioration of the environment. Proceed. of Inter. Govt. Conf. of Experts on Sc. basis for rational use and cons. of the biosphere. Paris 4-13 Sept. 1968.

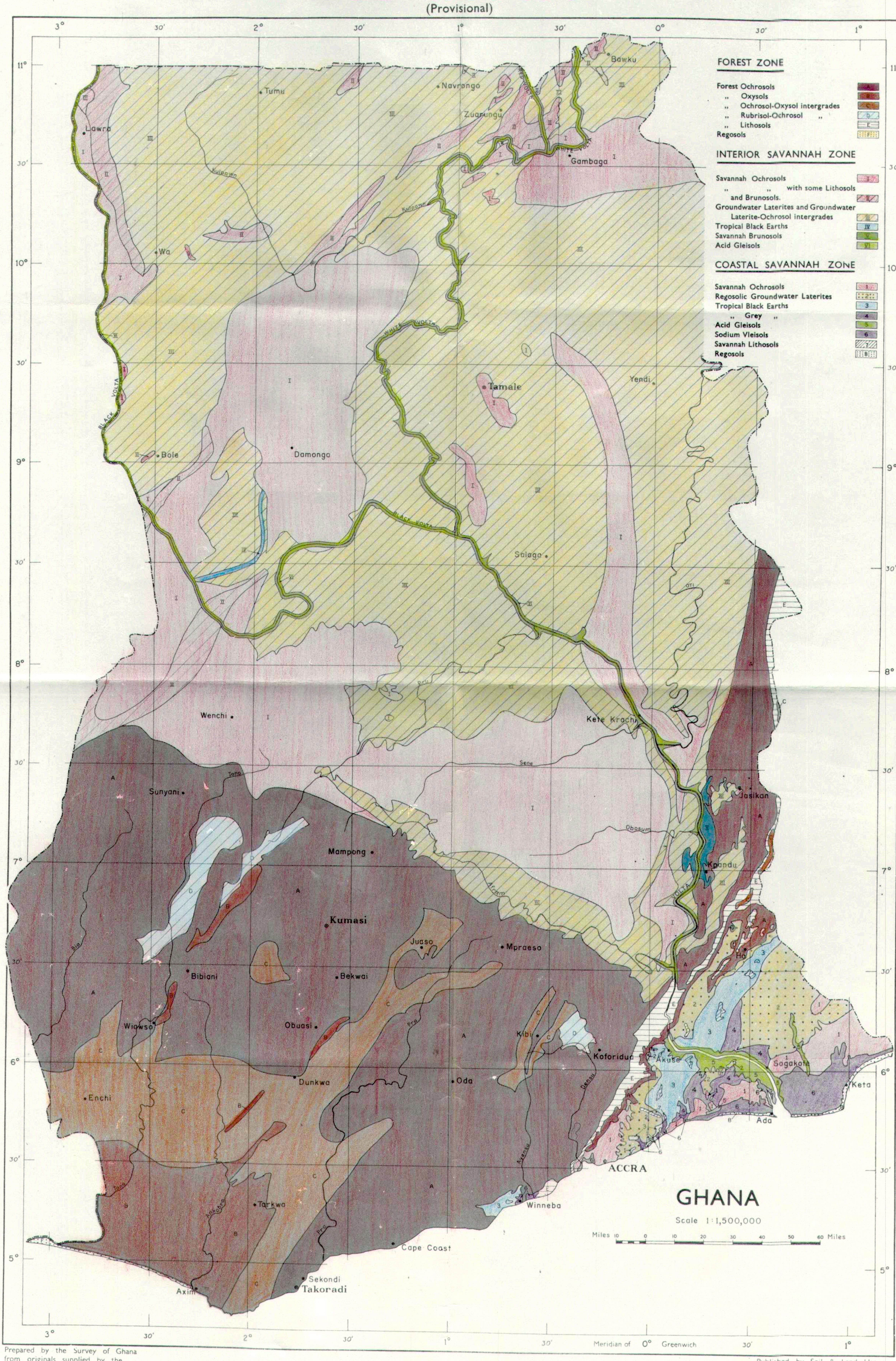
Working Plans Branch Ghana. Boin-Disue-Yoyo WP.1960-1965.
Bonsa River F.R. WP.159-1964.
Bia Group WP.1957-1962.
Ho Hill Station WP.1958-1964.
Kwamisa F.R. WP.1958-1963.
Mamiri Group WP.1958-1963.
Oda River F.R. WP.1958-1969.
Asenanyo F.R. WP.
Bosomoa F.R. WP.

Worley, P.D. Local benefits from Timber Industry Expansion. USDA Central Expt. Stn. Paper 172.

Worrell, A. 1970. Principles of Forest Policy. McGraw-Hill Inc. N.Y.

Zivnuska, J.A. 1966. Integration of Forest development plans and national development plans, how to make the forestry case at the national level. Proceed. of World For. Congress, 1966.

MAP 4 GREAT SOIL GROUPS
(Provisional)



Prepared by the Survey of Ghana from originals supplied by the publishers 1958.

Published by Soil & Land Use Survey Division of the Department of Agriculture, Ghana.